VOLUME 28 NUMBER 1

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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

OCTOBER, 1906

CONTENTS

Frontispiece: The Engineering Building — Opposite Title Page

List of Officers — 4

Society Affairs — 5

Salutatory

Convention News

Miscellaneous Announcements

Accessions to the Library — 9

Employment Bulletin — 10

Suggestions to Authors — 10

Papers

Report Machine Screw Committee — 19

Ventilation of Boston Subway. H. A. Carson — 50

Ferroinclave Roof Construction. A. E. Brown — 65

Saw-Tooth Skylight in Factory Roof Construction. Fred S. Hinds — 77

NEW YORK MEETING, DECEMBER 4-7, 1906

Application has been made at the post office in Baltimore to have this publication entered as second-class matter under the Act of July 16, 1894.

THE ENGINEERING BUILDING
(From the latest photograph)
By courtesy of the Bi-Monthly Bulletin, A.I.M.E.

OCTOBER, 1906 VOL. 28. No. 1

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

CONTAINING PAPERS
TO BE PRESENTED AT THE NEW YORK MEETING
DECEMBER 4-7, 1906

PUBLISHED MONTHLY BY
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1905—1906

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PROCEEDINGS
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 28 OCTOBER, 1906 NUMBER 1

BRING THIS COPY WITH YOU TO THE MEETING

NOTE—The professional papers contained in this number of Proceedings are sent to you that you may prepare any discussion of them which you may wish to present. They are issued to the membership in confidence, and with the distinct understanding that they are not to be given to the press or to the public until after they have been presented at the meeting. All papers are subject to revision.

"The Society as a body is not responsible for the statements of facts or opinion advanced in papers or discussions." (C 55)

ANNOUNCEMENT

With our greetings, we are pleased to announce to the membership the regular publication of our Proceedings. Hereafter the first number will be issued in September of each year and the publication will appear monthly thereafter for ten months.

Proceedings will contain principally the advance papers and the written discussions for the several meetings of the Society. The series when revised after presentation will be republished in the usual bound volume of Transactions.

This plan was partially instituted this spring when the advance papers were issued in pamphlet form for the first time.

Advantage will be taken of this medium to acquaint the membership with the progress of the Society's work; with accessions to the Library; with the membership of various committees and their activities; and with matters of special interest such as progress on the Engineering Building, employment bureau notices and professional records of candidates for membership.

CONVENTION NOTES

The Society's Annual Meeting will be held in New York as usual in December, beginning the first Tuesday the fourth, and continuing through Friday the seventh.

The various sessions will be held in the Engineering Building. During the same days there will probably be held similar meetings of the other Founder Societies to serve as an informal opening of the Engineering Building. While this will not constitute the official opening and transfer from the Building Committee to the Societies, yet it will be an epoch in the history of the Society and engineering which no member ought to miss.

The suggestion has been made that the social side of the meetings would be facilitated particularly for the visiting ladies, if members having no choice, would stop at the same hotel. The suggestion is repeated here, coupled with the offer of the Secretary, to make his office a "clearing house" for the members to effect any arrangements mutually agreeable to themselves.

Just a word in regard to the Reception Committee, addressed to young men and particularly to those from a distance. Please understand that you are especially welcome and that you have a right to all the good you can obtain from a meeting with the men of your profession. The Reception Committee is composed of representative men and more than that each one is known to be an admirer of young men.

Each member will have a distinctive badge and you are cordially invited to make yourself known to them so they may introduce you to others in attendance at the meetings.

Application has been made to the Railroad Association governing this territory for certificate rates of a fare and a third for members attending the December meeting in New York. Although we have not received definite advice as yet it is expected that this rate will be granted. If it is granted by the Trunk Line Association which controls the territory in which the meeting is to be held, that Association will take the matter up with the other Associations throughout the country asking them to coöperate, and we hope that we may be able to secure the certificate rates of a fare and one-third from practically all points. Detailed announcement concerning this will be made in November Proceedings.

EARLY PUBLICATION OF YEAR BOOK

The "pocket list" of members, usually issued about midyear, was omitted this year for the reason that in May a very compact and convenient list was mailed to the membership as a feature of the campaign to introduce ourselves to new members. The Year Book giving very completely our membership will be issued about December 1, probably as an Appendix to No. 3 of our Proceedings. The membership will thus have received three lists in one year. All of the excellent characteristics and individuality of the former editions of the Year Book will be retained in this issue, it only being folded into the Proceedings. Members are urged to return promptly the requests to be sent out in October calling for changes of addresses, etc.

PRESERVATION OF FORESTS

All members interested in the movement for the better preservation of our forests are invited to communicate with the Secretary and advise in what way the Society can coöperate in this work. A resolution looking towards such cooperation was passed at the Chattanooga meeting.

SUGGESTIONS FROM MEMBERS

This spring the Secretary addressed a letter to each member, soliciting suggestions for the greater usefulness of the Society. This publication is a part of the result. All the suggestions have been acknowledged and the thanks of the Society offered. The replies have been carefully tabulated and segregated, referred to the several committees of the Society interested, and recommendations in turn made to the Council for action. The work is not yet done and many suggestions are to be undertaken as we have the means.

This may suggest to readers other thoughts. Please send them in to the Secretary at once, who will gratefully receive them and so far as practicable incorporate them into the activities of the Society.

THE SOCIETY HOUSE

Rooms at the Society House, 12 West Thirty-first street, are available to members and their families. Owing to the crowded condition of the hotels the members will find the house especially convenient.

THE NOVEMBER NUMBER

The November number of Proceedings will be issued November 1, so as to meet the Constitutional requirements that all papers for presentation at a meeting be issued at least 30 days prior to the meeting. Written discussion on papers in the current number can appear in the November number if copy is mailed at once. The forms for the November number will close October 10 to 15 according to the character of the copy. Written discussion received at the office after the forms for the November number have closed will be included in the December number.

PROGRESS ON THE ENGINEERING BUILDING

As may be inferred from the announcement as to the place of holding the Convention work on the Engineering Building is rapidly nearing completion. With the exception of the trim on several floors and the painting and decorating the new home of the Engineering Societies is practically finished. At the time of holding the Convention it is expected that all the workmen except perhaps the decorators will have vacated the building.

LIBRARY ACCESSIONS

A List of Books of Technical Interest Recently Added to the Library

Boiler Construction. By F. B. Kleinhans. *Locomotive Publishing Company, New York, 1904.*

Cam Construction. By George Jepson. *D. Van Nostrand & Co., New York, 1905.*

Cement, Mortars and Concretes. By Myron S. Falk. *The Myron C. Clark Company, New York, 1904.*

Electric Haulage. By L. R. Pomeroy and W. B. Potter. *Publications of General Electric Company, Schenectady, New York, 1905.*

Eminent Engineers. By Dwight Goddard. *The Derry-Collard Company, New York, 1906.*

Handbook of Cost Data. By H. P. Gilette. *The Myron C. Clark Company, New York, 1904.*

Heat and Light from Municipal Waste. By Joseph G. Branch. *The Wm. H. O'Brien Printing Company, St. Louis, Mo., 1906.*

Locomotive Tests. *Pennsylvania Railroad Company, Philadelphia, 1905.*

Mineral Oils. By Iltyd I. Redwood. *E. & F. N. Spon, Ltd., London, 1897.*

Modern Steam Turbine. By John Wolf Thurso. *D. Van Nostrand & Co., New York, 1905.*

Pocket-Book of Mechanical Engineering. By C. M. Sames. *C. M. Sames, Jersey City, N. J., 1905.*

Railways in the United States in 1902. Report of the Interstate Commerce Commission. *Washington, D. C., 1903, 5 vols.*

Report of Engineering Standards Committee. *London, 1905.*

Shaft Governors. By W. Trinks and C. Housam. *D. Van Nostrand & Co., New York, 1905.*

Statistics of Railways in the United States. Interstate Commerce Commission. *Washington, D. C., 1904.*

Steam Turbines. By A. Stodola, translated by *Louis C. Loewenstein, New York and London, 1905.*

Steam Turbines. By C. C. Thomas. *John Wiley & Sons, New York, 1906.*

Tables of Steam Engineering. By E. Godfrey. *Pittsburg, Penna., 1905.*

The United Otto System of By-Product Coke Ovens. *United Coke and Gas Company, New York, 1906.*

Ventilation of Buildings. By W. G. Snow & T. Nolan. *D. Van Nostrand & Co., New York, 1906.*

EMPLOYMENT BULLETIN

NOTE—The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both as to positions and men available.

POSITIONS AVAILABLE

01 Mechanical engineer, technical school graduate, experienced in ice and refrigerating machinery, both manufacturing and operating, wanted as outside trouble man by large firm of manufacturers. Location, New York.

02 Man thoroughly familiar with most modern and approved foundry practice and the building of automatic engines, to take charge of operating department as superintendent. Location in Ohio.

03 Mechanical engineer or good draftsman with experience in laying out and installing steam, water, air, Pintsch gas, piping systems, etc. Location, New York.

04 Well established business in the manufacture of steam engines is in need of a thoroughly experienced man, competent to undertake the manufacture and general direction of the business. Location, New York State. Salary adequate to the man and the position.

05 Wanted an electrical and gas engineer, competent to pass on properties and make technical and financial reports on same. Location, New York State. Salary, $4000.

06 Wanted a mechanical engineer with at least seven to ten years' experience in concrete cement machinery and general construction. Salary depends on experience, $35 to $50 per week. Must be able to survey and be a good draftsman.

07 Man of high attainments, educationally and mechanically, to organize and successfully carry on a series of educational classes for the development of apprentices and other young men employed, from whose ranks may be secured the future foremen, superintendents and managers. Location, Ohio.

08 Wanted by large concern in New York, energetic and very able young engineers. Location, New York.

09 Draftsmen to do electrical and mechanical work. Young men willing to start with about $18 a week. Location, New Jersey.

010 Draftsmen wanted by New York concern.

011 Mechanical draftsman or engineer familiar with mill construction and heavy timber work for the design of coal handling and conveying machinery, coal storage and retail yard work. Location, Pennsylvania.

MEN AVAILABLE

1 Mechanical engineer, experience with different concerns at the bench, as wood and metal pattern machinist, draftsman and engineer, in designing and perfecting typewriting machines, as superintendent and in charge of shop. Designed, perfected and superintended manufacture of large number of machines and devices in four different lines that are being successfully manufactured at this time.

2 Mechanical engineer; technical graduate with 12 years' practical experience as chief draftsman, chief engineer, superintendent, master mechanic and manager in power plant installation, power transmission, shop management and design and construction of light, heavy and automatic machinery. Best of references.

3 Member with experience of four years as mechanical engineer, six years as engineer salesman Crane Elevator Co. of Chicago, four years as district office manager in charge of sales and erection of machinery. Commercial experience with hoisting machinery, elevators, engines, pumps and boilers.

4 Member, age 31, experience in installation, maintenance and operation of mill and factory machinery. Successful in handling help, designing special machinery, repair shop methods and boiler practice. Expert in methods pertaining to manufacture of products from grains. Desires position as mechanical superintendent or chief engineer.

5 Shop manager, practical machinist, most experience has been with large steel company; traveled both in this country and Europe for different firms. Prefers directing of shop but would consider traveling; location does not matter.

6 Technical graduate, five years designing electrical machinery, including d. c. motors, controllers, etc.; five years operating steam and electrical plant, two years in consulting engineer's office, designing and testing steam and electric plants, also familiar with heating and ventilation of buildings.

7 Mechanical engineer of creditable, technical, personal and general qualifications, and with successful professional record, desires to join faculty of high grade technical college in the departments of mechanics or experimental engineering.

8 Mechanical engineer or chief draftsman with manufacturing concern. Technical graduate with 20 years' experience as draftsman, designer and instructor in mechanical engineering. New England preferred.

9 Mechanical engineer, member, now superintendent and chief engineer of a large plant building Corliss engines and other machinery, desires change. Position as manager or general superintendent preferred.

10 Mechanical engineer, 12 years' experience in shops, technical graduate and thoroughly competent; manufacturing lines preferred. Position as superintendent or manager.

11 Shipyard manager or superintendent, by a man of 23 years' experience in engine, hull and managing departments.

12 Merchant engineer and factor will introduce in Great Britain, Germany, Belgium, France and Austria, the special product of American firms, dispose of their foreign patents and organize subsidiary companies. Will also act as investigator and purchasing agent for individuals and firms desiring information regarding special processes, equipment and materials best obtainable in any of these countries. Office in London. Member.

13 Technical graduate with several years' experience in various lines of engineering work.

14 Young engineer, now in charge of important work for foreign corporation, desires connection of a responsible character with an American concern. Technical training (Cornell), commercial and engineering experience and a clean record.

15 Young man, mechanical engineer, desires position as superintendent, assistant or position of responsibility; good shop, drawing room and business experience, on engines, pumps, condensers, etc.; good executive ability; best of references.

16 Junior member; technical graduate, one year instructor in mathematics, two years marine engine draftsman, three years in the Bureau of Steam Engineering, U. S. N., on inspection duty, with special attention to the installation and tests of machinery, on board ship, also estimating on machinery and costs. Instructor for three years in steam engineering evening class work, including laboratory exercises. Desires responsible position in engineering firm. Marine engineering preferred.

17 Development or introduction of new mechanical devices, as manager or mechanical engineer, or work of similar character. Salary, $3000.

18 Experienced in design, organization, equipment, manufacture, etc., of fine productions, especially typewriting machines and would like to correspond with any one who may want such help. Prefer concern where position will be in mechanical charge and later invest small amount in concern.

19 Position as superintendent or mechanical engineer; 20 years' experience, 6 as superintendent, 10 as designer on steam and combustion engines, electrical apparatus, calculating machines, special machine tools for both heavy and light work, jigs, devices, etc., for economical manufacture.

20 Mechanical engineer, age 30, technical graduate, with extensive experience in steam turbines, Corliss high speed and internal combustion engines, desires responsible engineering and sales position.

21 Mechanical engineer, technical education, Junior member, experienced in design and construction of ballast, plantation, and contractors' dumps, and industrial cars. Outside experience in inspection and traveling. Past three years engaged as mechanical engineer with New York car manufacturing company. New York City location preferred.

22 Competent turbine engineer is open for a position as designing engineer, assistant or superintendent; age 28, single, technical training; has had five years' exclusive experience in turbine design.

23 Associate member desires a position as assistant superintendent, chief draftsman, or mechanical engineer; 16 years' experience on engines, pumps, compressors, saw-mill machinery, interchangeable work, etc., in drawing-room, shop and outside.

24 Mechanical engineer, technical graduate with considerable general and business experience, desires position in charge of mill construction or assistant manager of operation.

25 Member, graduate of Stevens (now in New York), with varied practical experience of mining and ore treatment machinery at home and abroad, and five years' commercial and executive experience in London branch of American firm, would like to represent mining machinery or other house in America, Europe or elsewhere. Fluent correspondent (French, Spanish), tactful, energetic.

26 Member, occupying an executive position with large manufacturer, seeks an engagement with either the manufacturing or sell-

ing department of some concern in similar lines. Steam engines, turbines, electrical apparatus.

27 Junior member, Michigan graduate, with 16 years' practical experience; now chief draftsman with a large manufacturing concern, desires position with a commercial vehicle or gasoline engine firm; 3 years' exclusive experience, including personal designs, on delivery wagons and trucks, from 1500 lbs. to 6 tons, sight-seeing vehicles, gasoline railroad cars, gasoline locomotives, marine engines, etc. Familiar with foreign practice. Competent to handle correspondence and orders, office or drafting room force. Desires position as mechanical engineer, chief draftsman, or assistant superintendent.

28 M. I. T. '94, post-graduate course in electrical engineering. General experience in design and in charge of product of company engaged in manufacture of steam and electric hoists, derricks of steel and wood, locomotive cranes up to capacity of 40 tons. In government work conducted physical tests upon materials used, including two large steel frame shop buildings, as well as smaller brick, stone and wooden buildings. Also extended experience with company manufacturing electrically operated water-tight bulkhead doors for ships, having installed apparatus on 32 of largest ships of the U. S. Navy. Desires work of general engineering character.

29 Special work desired outside of office hours, by mechanical engineer and university graduate. Member of the Society resident in New York.

30 Chief engineer or purchasing agent will consider proposition from a large coal consumer. Graduate mechanical engineering; considerable chemical work; firing and conducting boiler tests for seven years, three of which with one of largest coal companies in the United States; well acquainted with operating and sales ends of coal business.

31 Junior member, now holding technical position with large manufacturing firm, desires change to selling or consulting work. Has had exceptional experience covering design and economic performance of steam engines and air compressors, and is thoroughly familiar with best practice in the production and use of compressed air. Western location preferred.

32 Wanted a position as Superintendent of Construction of electric and hydraulic plants, familiar also with steam isolated plants, general office engineering; 6 years' experience. Technical graduate.

33 British mechanical engineer of 16 years' experience in work of exceptional variety comprising steam, electric, compressed air and hydraulic power plant practice; traction work; design, construction

and operation of cement and other industrial works; specification, inspection and installation of general machinery; excavations, foundations and buildings. For past two years in New York City carrying out extensive public works for large contracting firm.

34 Technical graduate, 33 years of age, married. Fourteen years' shop and drawing-room experience on general machinery, particularly special medium and heavy machine tools. Thoroughly familiar with modern shop practice and economy of production. Held positions as chief draftsman and designer, assistant to superintendent. Four years' commercial traveling and office experience. Location, New York or vicinity, as mechanical engineer, assistant superintendent or representative, competent to fill responsible position.

SUGGESTIONS FOR AUTHORS

On the Preparation of Papers for The American Society of Mechanical Engineers

Note.—The following is a tentative draft printed here with the hope that the membership will make further suggestions.—Editor.

In preparing a paper for presentation before a professional society, or for publication, there are some general principles, the observance of which will add greatly to the value of the work. These principles do not relate to the subject matter directly, but rather to the manner of presentation.

In the first place, a paper should, and generally does, relate to some especial department of work with which the author has had experience, so that he is very apt to assume many things as matters of common knowledge, when in fact they are not nearly so familiar to most of the audience as they are to himself. It is not usually a mistake to be too clear, particularly in the preliminary statements. Avoiding undue assumptions as to the familiarity of the audience with the subject, the general form of a paper should be about as follows:

GENERAL FORM OF PAPER

State first, in a brief and clear manner, just what the paper is about, what the author is endeavoring to show, or what he expects to prove. This introductory statement should be *very brief*, and having been made it should be kept in mind throughout. A paper should be about but one thing at a time, and that one thing plainly stated at the start.

Then should follow the general treatment; description of work, of experiments, of opinion, etc., this portion constituting the matter usually forming the body of technical articles or papers.

After this should come what may be called "proof," that is, a statement showing how the general matter immediately preceding has demonstrated what the author set out to show.

Finally there should come a very condensed summing up, in such a form that a brief glance would enable a casual reader to grasp the substance of the paper, and decide without reading the whole, whether or not he wants to examine it in detail.

The introductory statement, and the final conclusions, should in every case, enable the reader to get at the kernel of the whole matter, of which the bulk of the paper should be the detailed and expanded treatment.

The use of tables should be avoided whenever it is practicable to present results in a summarized form and where the tables do not make in themselves a distinct addition to the value of the paper.

Papers may be divided into two classes: those which give a record of experience or investigation in a formal manner, presented mainly for the purpose of putting the subject upon the official record; and those intended to arouse discussion, and presented for the very purpose of eliciting the opinions and experience of members at the meeting.

The purpose of the second of these classes cannot be successfully attained unless the original paper is in a form which permits the argument to be readily grasped. Many members do not have the opportunity of examining the paper until a few minutes before it is presented, and yet these should be able by a glance at the introduction and the conclusion, to decide whether it is a subject which they can discuss. Results of investigations are sometimes given in final form only, as tables or plotted curves, and while these are both most desirable, there should always be a general summing up of the leading results of importance in plain language, for immediate absorption by any one.

In nearly every case these simple principles may easily be followed, without imposing any hardship upon the author of the paper and without making it necessary for him to modify in any way his own style or general method of treating a subject.

ILLUSTRATIONS FOR REPRODUCTION

A few points relating to the reproduction of papers in the printing office may be added, as of much importance to the Publication Committee.

Write plainly on one side of the paper. Number the sheets consecutively in the upper right hand corner and have them of a uniform size. A good size is $8\frac{1}{2}$ x 11. It is desirable to have manuscript typewritten when this can be done without undue inconvenience. Give dimensions, etc., in the English system. If desirable the metric equivalents can be bracketed.

Put your full name and address on all manuscripts. Copy should be sent flat never rolled and preferably not even folded. Never fold illustrations intended for reproduction. Tracings may be sent rolled in mailing tubes.

DRAWINGS

All diagrams, drawings, etc., should be made on separate sheets of paper and if possible so as to bear photographic reduction to the standard page size of the Transactions. Photo-engraving is reliable and accurate, and greatly to be preferred to any process which requires the illustration or diagram to be redrawn. Good tracings can always be reproduced, but the reduction should not have to be more than one-third, preferably one-half, the linear dimensions of the original. Since the width of the type measure of the page is $4\frac{1}{8}$ inches a drawing to be reduced to page-width should not be more than eight to twelve inches wide.

In making drawings intended for reproduction it is well to exaggerate the size of all numerals and dimensions so that under reproduction on a reduced scale they will still be legible. The greater the reduction the heavier should be the lines to give sharp results. As the height of the page is 7 inches the proportion of height to width in copy should be about 1.7 to 1. Any drawing of these proportions will, when reduced by photography, fill a page correctly. Do not use red ink, as it does not reproduce.

PHOTOGRAPHS

In selecting photographs or making photographic prints for illustrations, it should be remembered that the glossy solio prints are better suited for reproduction than velox, or other matte surface paper, besides bringing out all the detail in the negative to the best advantage. Photographs should not be printed too deep, and the reproductions are better made from prints of a slightly reddish tone than from those over-toned to a bluish tint.

All copy intended for illustrations should be clearly marked with the title, subject and author's name, a reference to the manuscript to which it relates, and all other data of interest. This had better be written on the back in pencil; ink is apt to show through, especially when written on the back of light portions of a photograph.

The places where plate and figure references are to be inserted in the text should be indicated in the manuscript. Illustrations should only be used where necessary for the elucidation of the text—never for mere embellishment.

A list of illustrations giving their titles in brief should accompany the manuscript.

By paying attention to the above notes it is believed that the appearance of the Transactions will be improved, the extent and character of the discussions greatly improved, and the work of the Society materially facilitated, without casting any additional burden upon the members whose interest in that work prompts them to contribute from the richness of their experience to the Transactions.

Address all communications in regard to contributions to "The American Society of Mechanical Engineers, 12 West 31st Street, New York City."

REPORT OF THE COMMITTEE ON STANDARD PROPORTIONS FOR MACHINE SCREWS[1]

1 The Committee, having been intrusted with the consideration of a standard for the proportions for machine screws, has the honor to present the following report:

2 At a joint meeting held in New York, April 11, 1904, certain diameters, pitches and limits for standard machine screws were unanimously agreed upon, including recommendations as to the best practical methods for establishing and maintaining such standard sizes, pitches and limits. At this meeting there were present, representing the screw manufacturers: Mr. Charles Glover, President, The Corbin Screw Corporation, New Britain, Conn.; Mr. Benjamin Thurston, General Superintendent, American Screw Company, Providence, R. I., and The Worcester Machine Screw Company; Mr. E. O. Goss, Treasurer, The Scovill Manufacturing Company, Waterbury, Conn.; and the members of your Committee, Mr. Wilfred Lewis, Chairman; Mr. Charles C. Tyler, Mr. Horace K. Jones, Mr. George R. Stetson, Mr. J. F. Madgett, Assistant Superintendent, General Electric Company (representing Mr. John Riddell, member of Committee); and Mr. George M. Bond.

3 Since the date of this joint meeting, however, it has been found advisable to modify the list of machine screw sizes which were agreed upon at that time, to exclude the diameters 0.3125 ($\frac{5}{16}$ in.) and 0.4375 ($\frac{7}{16}$ in.), these being already included and established under the Sellers or United States Standard System, well known and designated fractionally, and to replace them by the addition of three sizes, as follows:

0.240	24 per inch
0.270	22 "
0.320	20 "

[1] Presented at the New York Meeting (December, 1905), at the Chattanooga Meeting (May, 1906), and to be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and forming part of Volume 28 of the Transactions.

4 These additional sizes all closely approximate regularly listed machine screws corresponding, and have been, and are now made in large quantities. The further advantage considered by your Committee in recommending this change is that the three new sizes, and all in the list as now proposed and agreed upon, require but three decimal places to express their exact diameter, while those rejected involve the use of four.

5 It was also found advisable to change slightly the limits of variation for the taps corresponding to the sizes of machine screws agreed upon, to allow for possible errors in the lead or pitch of the thread and in the diameter, due to hardening, unavoidable in their manufacture.

6 In the consideration of this subject, your Committee believes the following combined details to be essential in establishing and maintaining a standard for the diameters, threads and heads of machine screws, including, as it does, diameters, threads and limits for the taps which are to be used in connection therewith:

a form of thread,
b diameters,
c number of threads per inch,
d standard reference thread gages, basic and for screws and taps,
e working gages for screws and for taps,
f limits of variation, measured in the angle of the thread,
g limits of variation in external diameter,
h limits of variation in the pitch of the thread, screws and taps,
k proportions of the heads.

FORM OF THREAD

7 The Sellers, or U. S. form of thread, having an included angle of 60 degrees, and a truncation or flat at the top and bottom of the thread equal to one-eighth of the pitch of the thread, shall be used for the basic standards.

8 The form of thread for machine screws shall have an included angle of 60 degrees, a truncation or flat at the top of the thread equal to one-eighth of the pitch, and a truncation at the bottom of the thread equal to one-sixteenth of the pitch.

9 The form of thread for machine screw taps shall have an included angle of 60 degrees, a truncation or flat at the top of the thread equal to one-sixteenth of the pitch, and a truncation or flat at the bottom of the thread equal to one-eighth of the pitch.

DIAMETERS

10 The diameters of machine screws shall be expressed in decimal sub-divisions of an inch.

11 The standard diameters for machine screws, when measured over the top of the thread, shall be the fourteen sizes given in Table 1.

NUMBER OF THREADS PER INCH

12 The standard number of threads per inch for the fourteen sizes of machine screws shall be those also given in Table 1.

STANDARD REFERENCE THREAD GAGES

13 As stated in a paper by Mr. Charles C. Tyler, on pages 608-9, Vol. 23, Transactions, in order "to secure the interchangeability of machine screws and taps, a practical system of gaging should be provided, and ultimate standards of reference are desirable, particularly in cases of disputed thread sizes. The modifications of the form of thread for screws and taps to give clearance, each being based on the United States standard thread, make it seem desirable to provide three sets of standard reference thread gages for each gage diameter; one basic, one for screws, and one for taps."

14 The thread dimensions of these standard reference thread gages are given in Table 2.

15 The pitch diameters, given in column 8, Table 2, are the diameters when measured in the angle of the thread, at points equidistant from the top and bottom of the threads of the basic standards.

BASIC STANDARD REFERENCE THREAD GAGES

16 Following further the text of Mr. Tyler's paper, referred to, with slight modifications, your Committee recommends as the foundation of the system, a set of basic standard reference thread gages, these gages to be made of unhardened steel, of 0.35 per cent to 0.40 per cent carbon, to represent exactly, in every detail, the U. S. form of thread, the diameter at the top of the thread, the diameter at the bottom of the thread, and the correct pitch; the included angle of 60 degrees, and the flat at top and bottom of the thread equal to one-eighth of the pitch. Each basic standard gage to have plainly marked thereon the diameter, number of threads per inch and "M. S.

Standard Basic'' (machine screw standard), as shown in Fig. 1, herewith. The basic standards to be used only for comparative calibra-

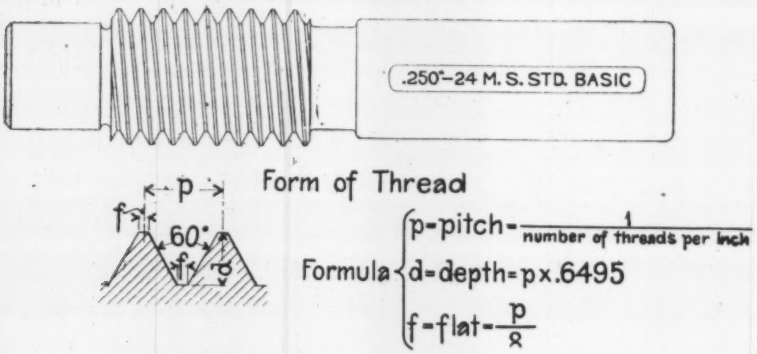


FIG. 1 BASIC STANDARD REFERENCE THREAD GAGE

tion, in the making of the reference standard plug thread gages for screws and taps. (See columns 5, 6, 7 and 8, Table 2.)

STANDARD REFERENCE THREAD GAGES FOR SCREWS

17 These gages are to be made also of unhardened steel, 0.35 per cent to 0.40 per cent carbon, to represent exactly, in every detail, a screw having the modified U. S. form, *i. e.*, a flat at top of one-eighth of the pitch, and at bottom of one-sixteenth of the pitch, with an included angle of 60 degrees, the exact diameter at the top and at the bottom of the thread, and the correct number of threads per inch. Each standard gage for screws to have plainly marked thereon the diameter, number of threads per inch, and "M. S. Standard Screw,'' as shown in Fig. 2, herewith.

18 The gages for screws should be exact duplicates of the basic standards, in external diameter, pitch and number of threads per inch, also in pitch diameter, measured in the angle of the thread, but to be less in diameter at the bottom of the thread, corresponding to the decreased width of flat, which at this point is one-sixteenth of the pitch. These decreased root diameters are given in column 10, Table 2.

19 All details for measurement, for basic and reference thread gages for screws, are given in Table 2, excepting only those for width of flat, which are given in Table 10, following.

STANDARD REFERENCE THREAD GAGES FOR TAPS

20 These gages are also to be made of steel, 0.35 per cent to 0.40

per cent carbon, unhardened, to exactly represent in every detail, the size of a threaded tap before being fluted, having the included

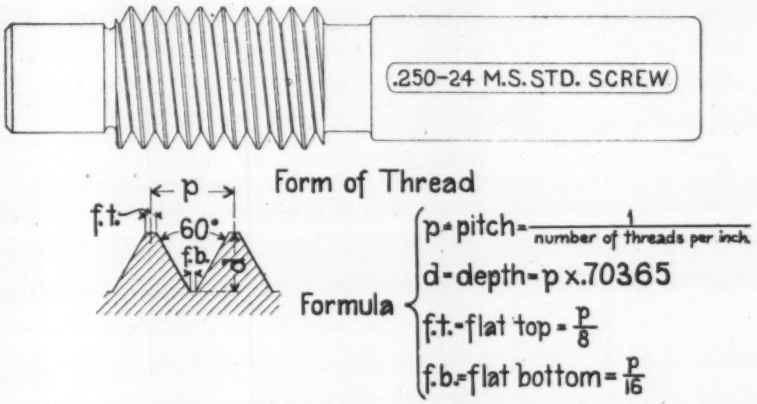


FIG. 2 STANDARD REFERENCE THREAD GAGES FOR SCREWS

angle 60 degrees, the flat at top one-sixteenth of the pitch, with flat at bottom of the thread equal to one-eighth of the pitch, and to correctly represent the standard pitch of thread. The external diameters to be as given in column 1, Table 2.

21 The increased external diameters there given are due to allowance for flat of one-sixteenth of the pitch and for error of lead due to hardening, as already mentioned. (See formula a, Table 8.)

22 The diameters at the bottom of the thread and in the angle at the pitch line, are given in columns 2 and 3, Table 2, as also the excess of pitch diameter over that of the basic standard, in column 4.

23 Each standard for tap gages to have the diameter, number of threads per inch and "M.S. Standard Tap" plainly stamped thereon, as shown in Fig. 3, on next page.

24 Standard reference thread gages for screws and taps should be used *only* for comparative calibration in making working gages for such screws and taps, and to detect by such measurement the wear of the working gages in actual service.

WORKING GAGES FOR SCREWS AND TAPS

25 The working gages for screws should be made of unhardened steel, and be exact duplicates of the standard reference thread gages for screws, in external diameter, in diameter at the bottom of the thread, in pitch and in diameter measured in the angle of the thread;

each working gage for screws to have the diameter, number of threads per inch and "M. Screw" plainly stamped thereon.

26 For inspection of screws, your Committee recommends the use of templet thread gages, made of steel, hardened, double end, plus and minus limits respectively, the holes being tapped to repre-

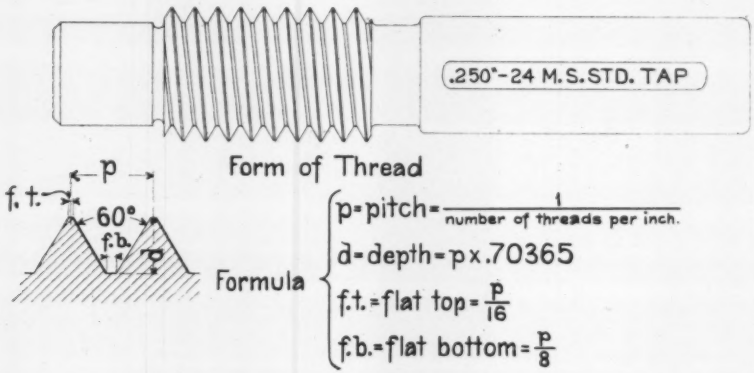


FIG. 3 REFERENCE THREAD GAGES FOR TAPS

sent accurately the limits for screws given in columns 3 and 6, Table 5. The thickness of these templet thread gages for each size screw is given in Table 9, and is designed to admit at the maximum end all screws that are within the limits, and to reject all that are larger, while screws smaller than the minus end of the templet gage are thus shown to be less in diameter than is specified by the minimum limit recommended by your Committee.

27 The working gages for taps should also be made of unhardened steel, and to be exact duplicates of the standard reference thread gages for taps, in external diameter, in diameter at the bottom of the thread, in pitch and in diameter measured in the angle of the thread; each working gage to have the diameter, number of threads per inch and "M. S. Tap" plainly marked upon it.

28 The handles of all working gages to be of a form easily distinguished from that of the reference gages.

LIMITS OF VARIATION IN SCREW AND TAP DIAMETERS

29 It is obvious that the thread sizes of machine screws and taps cannot be made commercially to correspond exactly with the standard gage dimensions herein recommended, and therefore estab-

lished limits of variation are provided to prevent further controversy if the sizes of either are in dispute.

30 To insure the satisfactory fit of a screw in a tapped hole, it is evident that the screw should not be larger than the maximum working gage, although it may be a trifle smaller; and that a tap should not be smaller than the minimum working gage, though it may be somewhat larger. The variation from the working gage size, therefore, should always be *minus* for the screw and *plus* for the tap.

31 The limits of variation for the diameters of machine screws, when measured in the angle of the thread, are determined by the formula

$$\text{Limit} = \sqrt{\text{Pitch}} \times 0.01$$

These limits are given in column 5, Table 3.

32 The limits of variation for the external diameter of machine screws, measured over the top of the threads, shall be determined by the formula

$$\text{Limit} = \sqrt{\text{Pitch}} \times 0.02$$

33 The limits for the fourteen sizes are given in column 4, Table 4. Limit diameters for machine screws, measured at the top of the thread, are given in columns 1 and 4, Table 5.

LIMITS FOR MACHINE SCREW TAPS

34 The minimum limits of variation for machine screw taps, measured in the angle of the thread, are given in Table 6.

The maximum limits, obtained by the use of the formula

$$\text{Max. Limit} = \sqrt{\text{Pitch}} \times 0.008$$

are also given in column 6, Table 6.

35 The maximum and minimum limit diameters for machine screw taps, measured at the top of the thread, are given in Table 7.

The maximum limit is determined by the formula

$$\text{Max. Limit} = \text{Min. Tap OD} + \sqrt{\text{Pitch}} \times 0.016$$

These limits are given in column 6, Table 7.

36 The Minimum Limit equals Basic Standard OD. $+ \sqrt{\text{Pitch}} \times 0.005 + \text{P}\ (0.10825)$. The maximum and minimum limit diameters for machine screw taps, measured at the top of the thread, are also given in Table 8, columns d and a, respectively, with the formulas for them, below the table.

37 Columns c and f give the excess of minimum and maximum pitch diameter of standard machine screw taps over the pitch diam-

eter of basic standard. These values will readily determine the correct size, within the limits recommended, of machine screw taps, using a micrometer fitted with spherical contacts and measuring in the angle of the thread, in comparing the diameter of taps with the reference standard gages.

LIMITS OF VARIATION IN SCREW AND TAP PITCHES

38 As screws and taps are likely to have errors of pitch or lead, this variation must be taken into consideration. To make proper allowance for this, due to changes in the lead of thread in the dies used for threading screws, and of taps in hardening, it has been determined by your Committee that for screws this allowance shall not exceed 0.004 inch, either plus or minus the standard gage, per inch of length of thread of screw.

39 For machine screw taps, this allowance, under advisement by representative manufacturers of taps, can reasonably be stated as 0.0015 inch, plus or minus the standard pitch, per inch of length of tap thread.

40 The limits of variation for threads of taps, measured in the angle of the thread, as given in Table 6, have accordingly been based upon this allowance. The plus amount in diameter of minimum taps given in column c, Table 8, is thus the excess above the pitch diameter of the corresponding basic standard, by the amount necessary to permit the maximum screw to enter a tapped hole made by a minimum tap. This is also governed by the thickness of the templet thread gage for each. This dimension for each size machine screw being given in Table 9.

41 To facilitate the work of establishing the necessary threading tools for the accurate production of basic and reference standard thread gages, Table 10 is given, as the accuracy of the width of flat, both at top and at bottom of the thread, together with the correct angle of 60 degrees, is particularly important in determining the exact pitch diameter of these standard basic and reference gages.

42 To present graphically, on an enlarged scale, the clearance, top and bottom of the thread, with the limit of variation between screw and tapped hole, the thread diagram here given, Fig. 4, (see folder, Plate 1, at end of this paper), on a scale of 10 inches pitch, shows in a marked degree, even though reduced to about one-half the relative limits, top and bottom and in the angle of the

thread, with the clearance at top and bottom of the thread resulting from the variation between maximum tap and minimum screw, recommended by your Committee.

43 The variation, plus and minus, for tap and screw, wholly plus for tap and minus for minimum screw, from the basic standard is also clearly represented by the diagram. The data included thereon will show the range of limit variation found desirable by your Committee for practical interchangeability.

44 Fig. 5 (see folder, Plate 1, at end of this paper) shows the relative proportions of sharp "V," U. S. and basic standard screw and tap standard, with screw and tap limits. Fig. 6 (herewith) shows

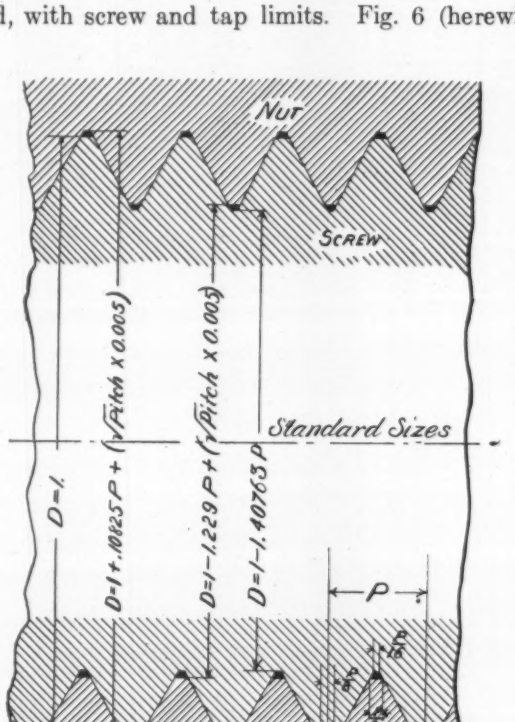


FIG. 6 STANDARD SCREW FITTING STANDARD TAPPED HOLE

the condition of a standard screw fitting a standard tapped hole, while Fig. 7 (see next page) exhibits the condition of greatest varia-

tion between them, including outside diameter, pitch diameter and error in lead of screw thread. Fig. 8 (see next page) shows the method of calibration recommended, using a spherical contact micrometer for the purpose of comparing reference gages with the basic standard thread gages, or working gages with the standard reference thread gages.

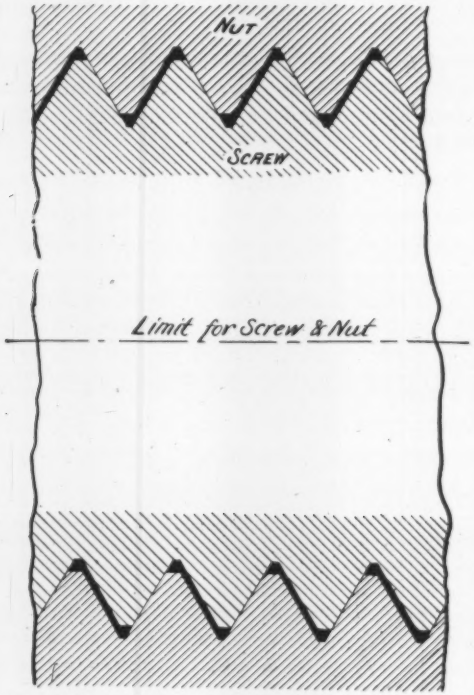


FIG. 7 GREATEST VARIATION BETWEEN STANDARD SCREW AND STANDARD TAPPED HOLE

45 This method can be relied upon for the accuracy required, and is especially adapted for duplicating thread diameters and for determining variations from the standard gages in the angle of the thread. It is an imperative condition, however, that the thread angle of all gages, screws and taps be 60 degrees.

STANDARD PROPORTIONS FOR MACHINE SCREW HEADS

46 Through their courtesy and the interest taken in the matter of a standard for machine screws by the manufacturers represented at the joint meeting referred to, Tables 11, 12, 13 and 14, showing details

of standard proportions for round head, flat fillister head, oval fillister head and flat head machine screws are here presented, forming a part of the report of your Committee.

47 With each table the formulas are given, covering every detail required for establishing standard heads for the fourteen sizes machine screws considered and recommended by your Committee. As will be noted, these specifications are all based upon the diameter of the screw, thus reducing the calculations for each to its simplest form.

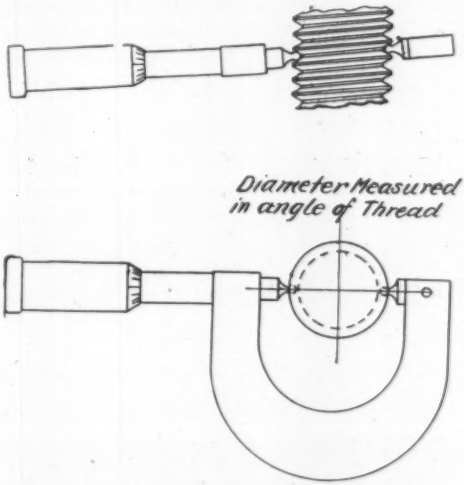


FIG. 8 METHOD OF CALIBRATION

48 The screws considered by your Committee have been confined to those used in great quantities by large manufacturers and are the class of production by machine screw manufacturers which are made from screw gage wire and having the heads formed by pressure. These are, therefore, known as pressed-head screws. They differ accordingly from those made by milling operation from stock of the nominal head diameters. The latter form a comparatively small proportion of the total production of so-called machine screws, and while in the aggregate are also largely used, are in many cases made to suit the requirements of the various manufacturers of machinery and machine tools, many of these being larger in body diameter than those which your Committee was asked to consider.

49 If the latter class of screws is to be standardized, a special committee might properly undertake this, and thus supplement the work already accomplished by your present Committee.

50 In conclusion, your Committee desires to record its appreciation of the courtesy and interest shown and assistance rendered by the representative screw manufacturers, which has thus made it possible for your Committee to complete its work.

51 Your Committee also wishes to acknowledge its obligation to Mr. J. M. Carpenter, President, the J. M. Carpenter Tap and Die Company, Pawtucket, R. I., and to Mr. F. G. Echols, Manager Small Tool Department, Pratt & Whitney Company, Hartford, Conn., for valuable information relating to machine screw taps, which has been included in the determination of the various limits for taps, recommended as necessary in this connection for securing practical uniformity, and consequent interchangeability.

Respectfully submitted,

WILFRED LEWIS, *Chairman*
CHARLES C. TYLER
HORACE K. JONES
JOHN RIDDELL
GEORGE R. STETSON
GEORGE M. BOND

INDEX TO TABLES

TABLE 1 Standard Machine Screws, Diameters and Threads per inch.
TABLE 2 Standard Reference Thread Gages, Basic and for Screws and Taps.
TABLE 3 Limits of Variation for Diameters of Machine Screws, measured in the angle of the Thread.
TABLE 4 Limits of Variation for External Diameters of Machine Screws.
TABLE 5 Limit Diameters for Machine Screws.
TABLE 6 Limits of Variation for Diameters of Machine Screw Taps, measured in the angle of the Thread.
TABLE 7 Limits of Variation for External Diameters of Machine Screw Taps.
TABLE 8 Limit Diameters for Machine Screw Taps.
TABLE 9 Thickness of Templet Thread Gages.
TABLE 10 Proportions of Machine Screw Standard Threads.
TABLE 11 Dimensions of Round Heads for Machine Screws.
TABLE 12 Dimensions of Flat Fillister Heads.
TABLE 13 Dimensions of Oval Fillister Heads.
TABLE 14 Dimensions of Flat Heads.

TABLE 1. STANDARD MACHINE SCREWS

Thread U. S. Form

STANDARD DIAMETER	NUMBER OF THREADS PER INCH
0.070 in.	72
0.085	64
0.100	56
0.110	48
0.125	44
0.140	40
0.165	36
0.190	32
0.215	28
0.240	24
0.250	24
0.270	22
0.320	20
0.375	16

TABLE 2. STANDARD REFERENCE THREAD GAGES

STANDARD GAGES FOR TAPS U. S. Form, except at Top of Thread, which is flat 1/8 Pitch				BASIC STANDARD Reference Thread Gages U. S. Form				STAND. GAGES FOR SCREWS U. S. Form except 1/8 flat at Root	
1 Diameter at Top of Thread	2 Diameter at Root of Thread	3 Pitch Diameter	4 Excess Pitch Diameter over Basic	5 Diam. Top of Thread	6 No. Threads per Inch	7 Diameter Root of Thread	8 Pitch Diameter	9 Diam. Top of Thread	10 Diam. at Root of Thread
.07209	.05255	.06157	.00059	0.070	72	.05196	.06098	0.070	.05046
.08732	.06533	.07548	.00063	0.085	64	.06470	.07485	0.085	.06301
.10260	.07747	.08907	.00067	0.100	56	.07680	.08840	0.100	.07487
.11298	.08366	.09719	.00072	0.110	48	.08294	.09647	0.110	.08068
.12821	.09623	.11099	.00075	0.125	44	.09548	.11024	0.125	.09302
.14350	.10831	.12455	.00079	0.140	40	.10752	.12376	0.140	.10482
.16884	.12975	.14779	.00083	0.165	36	.12892	.14696	0.165	.12591
.19427	.15029	.17058	.00088	0.190	32	.14941	.16970	0.190	.14603
.21981	.16955	.19275	.00094	0.215	28	.16861	.19180	0.215	.16474
.24553	.18689	.21396	.00102	0.240	24	.18587	.21294	0.240	.18136
.25553	.19689	.22396	.00102	0.250	24	.19587	.22294	0.250	.19136
.27599	.21202	.24155	.00107	0.270	22	.21095	.24048	0.270	.20603
.32653	.25617	.28864	.00111	0.320	20	.25505	.28753	0.320	.24964
.38302	.29506	.33566	.00125	0.375	16	.29381	.33441	0.375	.28704

NOTE — Diameter at Root of Thread, for Basic Standard Gages,

$$= \text{Standard Diameter} - \frac{1.2990381}{\text{No. Threads per Inch}}$$

Diameter at Root of Thread for Standard Gages for Screws = Basic Root Diam. $- P(0.10825)$

Diam. Top of Thread Standard Gages for Taps = Standard Diam. $+ \sqrt{P} \times 0.005 + P(0.10825)$

TABLE 3. LIMITS OF VARIATION FOR DIAMETERS OF MACHINE SCREWS
Measured in the Angle of the Thread

Minimum Limit = Standard Pitch Diameter $- \sqrt{\text{Pitch}} \times 0.01$
Maximum Limit being Standard Pitch Diameter

1 STANDARD DIAMETER	2 THREADS PER INCH	3 PITCH $\frac{1}{n}$	4 MINIMUM PITCH DIAMETER	5 LIMIT (MINUS) $\sqrt{\text{PITCH}} \times 0.01$
0.070	72	.013889	.05980	.00118
0.085	64	.015625	.07360	.00125
0.100	56	.017857	.08706	.00134
0.110	48	.020833	.09503	.00144
0.125	44	.022727	.10873	.00151
0.140	40	.025000	.12218	.00158
0.165	36	.027778	.14529	.00167
0.190	32	.031250	.16793	.00177
0.215	28	.035714	.18991	.00189
0.240	24	.041667	.21090	.00204
0.250	24	.041667	.22090	.00204
0.270	22	.045455	.23835	.00213
0.320	20	.050000	.28529	.00224
0.375	16	.062500	.33191	.00250

NOTE — In the figures given for diameters and limits, derived from the use of the formulas here recommended, preference has been given in each instance to the decimal following the fifth figure which is 5 or more, thereby increasing the fifth figure by one.

The apparent slight discrepancy in doubling the limits in some instances is thus explained. The difference is, however, so small as to be quite beyond the limit of micrometer measurement.

TABLE 4. LIMITS OF VARIATION FOR EXTERNAL THREAD DIAMETERS OF MACHINE SCREWS

Minimum Limit Diameter = Standard Diameter $- \sqrt{\text{Pitch}} \times 0.02$. (See col. 4, Table 5)
Maximum Limit Diameter being Standard Diameter. (See col. 1, Table 5)

1 STANDARD DIAMETER	2 NUMBER THREADS PER INCH	3 PITCH OF THREAD $\frac{1}{n}$	4 MINIMUM LIMIT $\sqrt{\text{PITCH}} \times 0.92$
0.070	72	.013889	.00236
0.085	64	.015625	.00250
0.100	56	.017857	.00267
0.110	48	.020833	.00289
0.125	44	.022727	.00301
0.140	40	.025000	.00316
0.165	36	.027778	.00333
0.190	32	.031250	.00353
0.215	28	.035714	.00378
0.240	24	.041667	.00408
0.250	24	.041667	.00408
0.270	22	.045455	.00426
0.320	20	.050000	.00447
0.375	16	.062500	.00500

TABLE 5 LIMIT DIAMETERS FOR MACHINE SCREWS
Measured at Top of Thread

MAXIMUM STANDARD DIAMETER			MAXIMUM STAND. DIAMETER = $\sqrt{\text{PITCH}} \times 0.02$		
1 Diameter Top of Standard Thread	2 Diameter Root of Thread	3 Pitch Diameter	4 Diameter Top of Thread	5 Diameter Root of Thread	6 Minimum Pitch Diameter
0.070	.05046	.06098	.06764	.04928	.05980
0.085	.06301	.07485	.08250	.06176	.07360
0.100	.07487	.08840	.09733	.07353	.08706
0.110	.08068	.09647	.10711	.07924	.09503
0.125	.09302	.11024	.12199	.09151	.10873
0.140	.10482	.12376	.13684	.10324	.12218
0.165	.12591	.14696	.16167	.12424	.14529
0.190	.14603	.16970	.18647	.14426	.16793
0.215	.16474	.19180	.21122	.16285	.18991
0.240	.18136	.21294	.23592	.17932	.21090
0.250	.19136	.22294	.24592	.18932	.22090
0.270	.20603	.24048	.26574	.20390	.23835
0.320	.24964	.28753	.31553	.24740	.28529
0.375	.28704	.33441	.37000	.28454	.33191

NOTE — Minimum Pitch Diameter = Standard Pitch Diameter $-\ 1\sqrt{\text{Pitch}} \times 0.01$
Col. 2 = Standard Root Diameter $-$ Pitch $\times$ 0.10825
Col. 3 = Col. 6 $+\ 1\sqrt{\text{Pitch}} \times 0.01$
Col. 4 = Standard Diameter $-\ \sqrt{\text{Pitch}} \times 0.02$
Col. 5 = Col. 2 $-\ \sqrt{\text{Pitch}}\ 0.01$
Col. 6 = Standard Pitch Diameter $-\ \sqrt{\text{Pitch}} \times 0.01$

TABLE 6 LIMITS OF VARIATION FOR DIAMETERS OF MACHINE SCREW TAPS
Measured in the Angle of the Thread
Minimum Limit = Pitch Diameter for Standard Taps. (See col. 3, Table 2)
Maximum Limit = $\sqrt{\text{Pitch}} \times 0.008$
Maximum Pitch Diameter = Maximum + Pitch Diameter of Standard Tap

1 STANDARD DIAMETER	2 NUMBER OF THREADS PER INCH	3 PITCH OF THR'D $\frac{1}{n}$	4 PITCH DIAMET'R MINIMUM TAPS	5 PITCH DIAMET'R MAXIMUM TAPS	6 MAXIMUM LIMIT $\sqrt{\text{PITCH}} \times 0.008$
0.070	72	.013889	.06157	.06251	.00094
0.085	64	.015625	.07548	.07648	.00100
0 100	56	.017857	.08907	.09014	.00107
0.110	48	.020833	.09719	.09834	.00115
0.125	44	.022727	.11099	.11220	.00121
0.140	40	.025000	.12455	.12582	.00127
0.165	36	.027778	.14779	.14912	.00133
0.190	32	.031250	.17058	.17199	.00141
0.215	28	.035714	.19275	.19426	.00151
0.240	24	.041667	.21396	.21559	.00163
0.250	24	.041667	.22396	.22559	.00163
0.270	22	.045455	.24155	.24326	.00171
0.320	20	.050000	.28864	.29043	.00179
0.375	16	.062500	.33566	.33766	.00200

NOTE — Col. 4 = Standard Pitch Diameter $+\ \sqrt{\text{Pitch}} \times 0.005$
Col. 5 = Col. 4 $+\ \sqrt{\text{Pitch}} \times 0.008$

TABLE 7 LIMITS OF VARIATION FOR EXTERNAL THREAD DIAMETERS OF MACHINE SCREW TAPS

Minimum Diameter = Standard Diameter + $\sqrt{\text{Pitch}} \times 0.005 + \text{Pitch} \times 0.10825$ (See col. 1, Table 2)

Maximum Diameter = Minimum Tap Diameter + $\sqrt{\text{Pitch}} \times 0.016$

1 STANDARD DIAMETER	2 NUMBER OF THREADS PER INCH	3 PITCH OF THREAD	4 MINIMUM DIAMETER	5 MAXIMUM DIAMETER	6 MAXIMUM LIMIT $\sqrt{\text{PITCH}} \times 0.016$
0.070	72	.013889	.07209	.07397	.00188
0.085	64	.015625	.08732	.08932	.00200
0.100	56	.017857	.10260	.10474	.00214
0.110	48	.020833	.11298	.11529	.00231
0.125	44	.022727	.12821	.13062	.00241
0.140	40	.025000	.14350	.14603	.00253
0.165	36	.027778	.16884	.17151	.00267
0.190	32	.031250	.19427	.19710	.00283
0.215	28	.035714	.21981	.22283	.00302
0.240	24	.041667	.24553	.24880	.00327
0.250	24	.041667	.25553	.25880	.00327
0.270	22	.045455	.27599	.27940	.00341
0.320	20	.050000	.32653	.33011	.00358
0.375	16	.062500	.38302	.38702	.00400

TABLE 8 LIMIT DIAMETERS FOR STANDARD MACHINE SCREW TAPS
Measured on Top of Thread

STANDARD DIAM. AND THREADS PER INCH	MINIMUM			MAXIMUM		
	a DIAMETER AT TOP OF THREAD	b DIAMETER AT ROOT OF THREAD	c EXCESS PITCH DIAMETER OVER BASIC STANDARD	d DIAMETER AT TOP OF THREAD	e DIAMETER AT ROOT OF THREAD	f EXCESS PITCH DIAMETER OVER BASIC STANDARD
0.070—72	.07209	.05255	.00059	.07397	.05349	.00153
0.085—64	.08732	.06533	.00063	.08932	.06633	.00163
0.100—56	.10260	.07747	.00067	.10474	.07854	.00174
0.110—48	.11298	.08366	.00072	.11529	.08481	.00187
0.125—44	.12821	.09623	.00075	.13062	.09744	.00196
0.140—40	.14350	.10831	.00079	.14603	.10958	.00206
0.165—36	.16884	.12975	.00083	.17151	.13108	.00216
0.190—32	.19427	.15029	.00088	.19710	.15170	.00229
0.215—28	.21981	.16955	.00094	.22283	.17106	.00246
0.240—24	.24553	.18689	.00102	.24880	.18852	.00265
0.250—24	.25553	.19689	.00102	.25880	.19852	.00265
0.270—22	.27599	.21202	.00107	.27940	.21373	.00273
0.320—20	.32653	.25617	.00111	.33011	.25796	.00291
0.375—16	.38302	.29506	.00125	.38702	.29706	.00325

NOTE—a = Standard Diameter + $0.10825 \times \text{Pitch} + \sqrt{\text{Pitch}} \times 0.005$

b = Standard Diameter = $\frac{1.2990381}{\text{No. Threads per Inch}} + \sqrt{\text{Pitch}} \times 0.005$

c = Minimum Tap Pitch Diameter − Standard Basic Pitch Diameter. (See col. 4, Table 6, and col. 8, Table 2)

d = a + $\sqrt{\text{Pitch}} \times 0.016$

e = b + $\sqrt{\text{Pitch}} \times 0.008$

f = Maximum Tap Pitch Diameter − Standard Basic Pitch Diameter. (See col. 5, Table 6, and col. 8, Table 2)

TABLE 9 THICKNESS OF TEMPLET THREAD GAGES

Thickness $= \sqrt{\text{Pitch}} \times 1.443$

STANDARD DIAMETER	THREADS PER INCH	THICKNESS
0.070	72	0.170
0.085	64	0.180
0.100	56	0.193
0.110	48	0.208
0.125	44	0.217
0.140	40	0.228
0.165	36	0.240
0.190	32	0.255
0.215	28	0.273
0.240	24	0.295
0.250	24	0.295
0.270	22	0.308
0.320	20	0.323
0.375	16	0.361

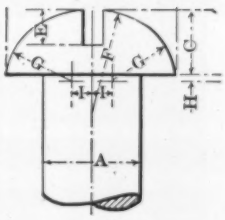
TABLE 10 PROPORTIONS OF MACHINE SCREW STANDARD THREADS

For Reference in making Threading Tools for Standard and Working Gages

1 DIAMETER AND THREADS PER INCH	2 PITCH $\frac{1}{n}$	3 WIDTH OF FLAT $\frac{1}{8}$ PITCH	4 WIDTH OF FLAT $\frac{1}{16}$ PITCH	5 DEPTH U. S. THREAD	6 DEPTH MACHINE SCREW THREAD	7 2 (DEPTH) U. S. THREAD	8 2(DEPTH) MACHINE SCREW THREAD
0.070—72	.013889	.001736	.000868	.00902	.00977	.01804	.01954
0.085—64	.015625	.001953	.000977	.01015	.01099	.02030	.02198
0.100—56	.017857	.002232	.001116	.01160	.01257	.02320	.02514
0.110—48	.020833	.002604	.001302	.01353	.01466	.02706	.02932
0.125—44	.022727	.002841	.001421	.01476	.01599	.02952	.03198
0.140—40	.025000	.003125	.001563	.01624	.01759	.03248	.03518
0.165—36	.027778	.003472	.001736	.01804	.01955	.03608	.03910
0.190—32	.031250	.003906	.001953	.02030	.02199	.04060	.04398
0.125—28	.035714	.004464	.002232	.02320	.02513	.04640	.05026
0.240—24	.041667	.005208	.002604	.02706	.02932	.05412	.05864
0.250—24	.041667	.005208	.002604	.02706	.02932	.05412	.05864
0.270—22	.045455	.005682	.002841	.02952	.03198	.05904	.06396
0.320—20	.050000	.006250	.003125	.03248	.03518	.06496	.07036
0.375—16	.062500	.007813	.003907	.04060	.04398	.08120	.08796

NOTE.—The formulas given in Tables 2 to 9, inclusive, for limits and other data required, are also applicable for establishing the reference gages for machine screws of any desired diameter of pitch of the thread, as well as for screws of the diameters given in Table 1, which are different in pitch, and therefore SPECIAL in their character; the thread in all cases being U. S. Form, with the modification of flat at top for taps, and at the bottom for screws being based upon the pitch of the thread in the same proportion.

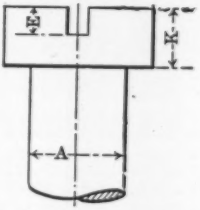
TABLE 11. ROUND HEAD FOR MACHINE SCREWS



A = Diameter of Body
B = 1.83A = Diameter of Head
C = 0.703A = Thickness of Head
D = 0.235A = Width of Slot
E = 0.40A = Depth of Slot
F = 1.095A = Rad. of Top of Head
G = 0.70A = Rad. of Sides of Head
H = 0.068A = Dist. from bottom of Head to center of G
I = 0.213B = Dist. from center of Head to center of G

A	B	C	D	E	F	G	H	I	Thr'ds per in.
.070	.1281	.0492	.0164	.0280	.0766	.0490	.0048	.0149	72
.085	.1555	.0597	.0200	.0340	.0931	.0595	.0058	.0181	64
.100	.1830	.0703	.0235	.0400	.1095	.0700	.0068	.0213	56
.110	.2013	.0773	.0258	.0440	.1204	.0770	.0075	.0234	48
.125	.2287	.0879	.0294	.0500	.1369	.0875	.0085	.0266	44
.140	.2562	.0984	.0329	.0560	.1533	.0980	.0095	.0298	40
.165	.3019	.1160	.0388	.0660	.1807	.1155	.0112	.0351	36
.190	.3477	.1336	.0446	.0760	.2080	.1330	.0129	.0405	32
.215	.3934	.1511	.0505	.0860	.2354	.1505	.0146	.0458	28
.240	.4392	.1687	.0564	.0960	.2628	.1680	.0163	.0511	24
.250	.4575	.1757	.0587	.1000	.2737	.1750	.0170	.0532	24
.270	.4944	.1898	.0634	.1080	.2956	.1890	.0184	.0575	22
.320	.5856	.2250	.0752	.1280	.3504	.2240	.0218	.0682	20
.375	.6862	.2636	.0881	.1500	.4106	.2625	.0255	.0799	16

TABLE 12. FLAT FILLISTER HEAD SCREWS

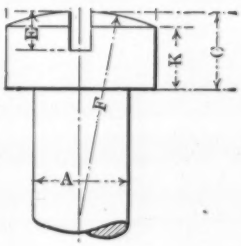


A = Diameter of Body
B = 1.6A = Diameter of Head
K = 0.65A = Thickness of Head
D = 0.235A = Width of Slot
E = 0.5K = 0.325A = Depth of Slot

A	B	K	D	E	Threads per Inch
.070	.1120	.0455	.0164	.0227	72
.085	.1360	.0552	.0200	.0276	64
.100	.1600	.0650	.0235	.0325	56
.110	.1760	.0715	.0258	.0357	48
.125	.2000	.0812	.0294	.0406	44
.140	.2240	.0910	.0329	.0455	40
.165	.2640	.1072	.0388	.0536	36
.190	.3040	.1235	.0446	.0617	32
.215	.3440	.1397	.0505	.0698	28
.240	.3840	.1560	.0564	.0780	24
.250	.4000	.1625	.0587	.0812	24
.270	.4320	.1755	.0634	.0877	22
.320	.5120	.2080	.0752	.1040	20
.375	.6000	.2437	.0881	.1218	16

TABLE 13. OVAL FILLISTER HEAD SCREWS

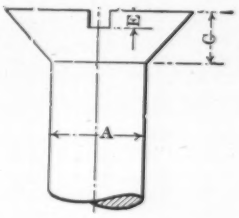
A = Diameter of Body
B = 1.6A = Diameter of Head
C = 0.80A = Thickness of Head (oval)
D = 0.235A = Width of Slot
E = 0.5C = 0.4A = Depth of Slot
F = 2.186A = Radius of Head
K = 0.65A = Thickness of Head (flat)



A	B	C	D	E	F	K	Threads per Inch
.070	.1120	.0560	.0164	.0280	.1530	.0455	72
.085	.1360	.0680	.0200	.0340	.1858	.0552	64
.100	.1600	.0800	.0235	.0400	.2186	.0650	56
.110	.1760	.0880	.0258	.0440	.2404	.0715	48
.125	.2000	.1000	.0294	.0500	.2732	.0812	44
.140	.2240	.1120	.0329	.0560	.3060	.0910	40
.165	.2640	.1320	.0388	.0660	.3607	.1072	36
.190	.3040	.1520	.0446	.0760	.4153	.1235	32
.215	.3440	.1720	.0505	.0860	.4700	.1397	28
.240	.3840	.1920	.0564	.0960	.5246	.1560	24
.250	.4000	.2000	.0587	.1000	.5465	.1625	24
.270	.4320	.2160	.0634	.1080	.5902	.1755	22
.320	.5120	.2560	.0752	.1280	.6995	.2080	20
.375	.6000	.3000	.0881	.1500	.8197	.2437	16

TABLE 14. · FLAT HEAD SCREWS

A = Diameter of Body
B = 2A — 0.0052 = Diameter of Head
$C = \frac{A - 0.0052}{1.739}$ = Thickness of Head
D = 0.235A = Width of Slot
$E = \frac{1}{2}C = \frac{A - 0.0052}{5.217}$ = Depth of Slot



A	B	C	D	E	Threads per inch
.070	.1348	.0373	.0164	.0124	72
.085	.1648	.0459	.0200	.0153	64
.100	.1948	.0545	.0235	.0182	56
.110	.2148	.0603	.0258	.0201	48
.125	.2448	.0689	.0294	.0229	44
.140	.2748	.0775	.0329	.0258	40
.165	.3248	.0919	.0388	.0306	36
.190	.3748	.1063	.0446	.0354	32
.215	.4248	.1206	.0505	.0402	28
.240	.4748	.1350	.0564	.0450	24
.250	.4948	.1408	.0587	.0469	24
.270	.5348	.1523	.0634	.0508	22
.320	.6348	.1816	.0752	.0605	20
.375	.7448	.2126	.0881	.0709	16

DISCUSSION

DECEMBER, 1905

MR. JOHN W. UPP Referring to Table 14: the practice among manufacturers of machine screws seems to be about equally divided between 80 degrees and 82 degrees for the angles of the sides of heads, but 80 degrees has been given the preference for the larger sizes of machine screws and cap screws of similar shape. Also 80 degrees is recommended by some of the leading authorities as the proper angle for rivet heads and we do not find any who recommend 82 degrees. We would, therefore, question the advisability of adopting 82 degrees as a standard, but would recommend 80 degrees.

53 For the larger sizes of machine screws the diameter of head, equal to twice the diameter of the body, gives a screw with a head unnecessarily large, and it has been found advisable in the practice of one large user of cap and machine screws to make B equal $1\frac{3}{4}$ A for screws of diameter $\frac{1}{4}$ inch and above.

54 Referring to Tables 12 and 13: We would also ask consideration as to the advisability of combining these two tables and adopting the modified fillister head screw with rounded corners, this style of screw being in quite general use, having been adopted as a substitute for the other two forms.

55 When machine screws are manufactured to the dimensions recommended by the Committee, we would suggest that they have some distinctive mark on the head. This will assist in preventing the confusion which will be the principal objection to adopting any standard which does not agree with present practice.

MR. E. O. GOSS I have before me a copy of the report of the Committee on the standardization of machine screws, and this report in all respects save one meets my approval. I will briefly state that the single exception is with regard to the width of the slot, which has been adopted as a function of the diameter of the screw.

57 It seems to me that inasmuch as we have already the American standard gage for the thickness of wire and sheet metals, and that screw slotting saws or cutters are made now, and kept regularly in stock, of a thickness gaged by the American or Brown & Sharpe's standard, if the new standard should be adopted for the width of the slot, it will necessitate rolling steel especially for the manufacture of screw cutting saws, which will entail an unnecessary expense and complication. I suggest, therefore, that in lieu of the Table 11, the dimensions should be made as follows:

A	D
.070	.016
.085	.020
.100	.023
.110	.025
.125	.028
.140	.0 2
.165	.040
.190	.045
.215	.051
.240	.057
.250	.057
.270	.064
.320	.081
.375	.091

58 The above tables of figures represent the nearest sizes which may be expressed in the gage numbers of the American standard wire gage, and the sizes proposed for the width of the slot, calculated on the formula 0.0235A, and I think will meet the objection above stated, without sacrificing anything either in the strength of the screw or any inconvenience of tabulation or manufacture.

MR. SANFORD A. MOSS It seems to me that a very great opportunity for simplification in machine work will be lost if the machine screw threads do not form a continuous series with the U. S. standard threads. In order to do this the 0.25 diameter should have 20 threads.

60 It is doubtful if any advantage is gained by having two kinds of $\frac{1}{4}$-inch types, and there does not seem to be any reason why the U. S. standard $\frac{1}{4}$-inch with 20 threads would not be perfectly acceptable for machine screws. Similarly the U. S. standard $\frac{5}{16}$ inch would be perfectly acceptable instead of the 0.32 20-thread size proposed.

61 It has always been a nuisance in shop practice to have "Machine Screw" and "U. S. Standard" types nearly but not quite alike, and it seems to me that one of the advantages of the proposed standardization will be lost if this duplication is not done away with.

MR. E. H. NEFF I was greatly interested in the paper presented by Mr. Tyler at the Boston meeting of this Society in 1902, and in the discussion which was presented on that paper. I have also noted with interest the report of the Committee appointed at Boston to consider the improvements that are to be made by standardizing the proportions of machine screws. Unfortunately, this report has only come into my hands a few days before this meeting, so that I have been unable to thoroughly examine the contents of it, and I

am quite sure that members who are remote from New York City will have scarcely more than received this report before it is presented here this morning. In view of the importance of this matter, and the lateness of the arrival of this report, it is my request that the formal discussion of this paper be carried over until the spring meeting, so that men who are interested in this subject may have time to digest it, and give it the widest possible discussion.

63 There are one or two points which I desire to touch on informally. With the system of gages proposed by Mr. Tyler, and adopted by this Committee, it seems to me there can be little criticism. If you refer to the original paper by Mr. Tyler, I think you will find that his complaint would be fully remedied by the adoption by screw manufacturers in general of uniform sizes all referred to a system of gages such as he proposed. The complaint is that screws as received are not uniform, and may not be what they are expected to be in size. All of this will be corrected by the adoption of uniform gages for the screw-thread sizes already in use, as illustrated in Table 1, page 605, Vol. 23, Transactions. I received only a few days ago a list from the American Screw Company, giving the identical sizes in this table, based on a common difference of about .013. If this Committee had seen fit to confine their labors to trying to get the screw manufacturers together on the standard sizes, as represented in this list already in use, they would have been performing a labor that would have some practical results, and to the greatest usefulness to users of machine screws.

64 Referring to Table 3: I call attention to column 5, which is based on a formula there given, giving the limits of sizes of machine screws to five decimal places, or in hundred thousandths inch. I call attention to column 3, giving the pitch to millionths of an inch. These are simply illustrations in my view of the application of a formula without any regard to its practical connection with measurements. I call attention to Table 9, in which the thickness of a gage is figured out by taking the square root of the pitch and multiplying by a constant, giving sizes which do not correspond to the United States Standard Gage for sheet metal, or, as far as I have been able to observe from a hasty examination, to any other gage. I call attention to Tables 11, 12, and 13, columns B, giving the diameters of heads of machine screws likewise figured out by a formula. Some of these approximate the American Standard Wire Gage sizes near enough so that the heads could be produced from bar stock, and most of them do not approximate any size within reasonable distance. While it is true that screws are largely made with upset heads, it is also true

that a large number of screws are made from bar stock, and the sizes of heads should, therefore, as nearly as possible, approximate the diameters of standard stock sizes, so that they can be made without undue waste of stock.

65 It is my claim that in using the formulas for diameter of heads of screws that they should use the result to obtain an approximate diameter. Having used the formula in this way, they should then select for that particular diameter of screw the nearest regular standard size of stock that would fit that case, making heads, say, .005 smaller in diameter than this diameter of stock, so as to allow some to remove for finishing. The man who makes screws out of bar stock is necessarily confined to commercial sizes. The man who makes upset head screws can just as well make his dies to produce these slightly modified diameters as any other, and they would then both work to the same standard. I would also call attention to the size of slots in screw heads, to which the same treatment should be applied. When they have used their formula to get the width of slot, they could then choose the nearest standard screw slotting cutter size as it appears in the "Tables of the Manufacturers of Screw Slotting Cutters."

66 I wish to refer briefly to paragraphs 44 and 45. This discusses the method of measuring screws and taps by micrometer with spherical anvils. This is an antiquated method of measuring, and, in fact, is no measurement at all. It calls for a tool which is exceedingly difficult to produce, as these spherical ends would have to be mounted in exactly the same planes, be of exactly the same size, and be kept at that size. In use they would only bear on points, so that they would very quickly wear flat. In my discussion of Mr. Tyler's original paper on p. 619, Vol. 23, Transactions, I called particular attention to the screw-thread micrometer. This tool has one anvil sharp and the other anvil with a V, so that by its use measurements are taken at opposite points on the diameter of the screw, giving accurately the pitch diameter of the screw or tap. It therefore affords a means of determining directly the exact size, without any reference to a standard, what the pitch diameter of a tap or screw is, this determination being read directly to thousandths, and, of course could be estimated to ten thousandths. It also furnishes a method of establishing sizes within close limits whether a party has standard gages or not. The V anvil swivels, and therefore takes note automatically of different leads of thread, whether the same be due to design or to poor workmanship. This tool in any event gives you the correct pitch diameter of the screw measured. It makes each determination an

original one, without the necessity of reference to a set of standards.

67 I am aware that criticism might be made of this tool, that the V anvil has flat sides which when pressed against the helical surface of the screw, would theoretically make the reading an oversize. This point, of course, was not lost sight of in designing this tool, and before it was presented to the public it was investigated by a man who has probably done more for the advancement of accurate measurements in this country than any other man, namely, Mr. Oscar J. Beale. His report was that for the screw sizes under discussion the inaccuracy would not be anything that you could measure.

MR. L. D. BURLINGAME I am another of those who have not had sufficient time to examine this report as I would like, and in the brief examination I have given it there are several recommendations of the Committee that at least seem to me surprising in the light of our experience at the Brown & Sharpe Manufacturing Company.

69 Among these are, first, the amount of flat for the tops of the threads. While the standard recommended, of one-eighth of the pitch, follows the United States standard, it was not originally intended to carry this standard down to such small sizes as this present report mainly deals with. Such a rule is subject to the same limitations that many formulas are unless a constant is used. By flattening these small threads one-eighth only, it gives too sharp a thread. Our practice is to flatten the smaller sizes to one-sixth of the pitch, and we do not flatten as much as one-eighth for the large sizes, one-twelfth being our standard, making a gradation from the larger to the smaller, which, considered in connection with the use of taps, seems more practicable.

70 Another point is that the formula gives too small a difference between the tap and the screw for clearance and wear, the tap in this case giving, for the size with 64 threads, a minimum of only 1-1000 of an inch clearance above the screw. The proportion of one-sixteenth of the pitch, the difference between the tap and the screw, gives very little for wear of the tap. Even in a screw with 32 threads it would be less than 2-1000, which is easily lost track of.

71 The pitches recommended by this report seem very well adapted to the diameters of screws which they cover. We have always felt the need of a finer pitch than the United States formula would give, not only for the small sizes, but up to one inch diameter; and it would seem now that this matter is under discussion that the report should include such screws as are needed in machine tool work.

72 No doubt, in choosing the diameters of these screws the Committee has been limited by wire sizes and sizes of screws made by large manufacturers, but it is certainly unfortunate, if this report is to be approved by The American Society of Mechanical Engineers, that it should contain sizes so irregular in their gradation. If we were not hampered by the past, we would make, preferably, a geometrical progression of sizes.

73 In taking up the matter of the proportion of heads of screws, it is to be regretted that manufacturers of commercial screws should vary so much from sizes considered desirable by our machine tool makers, both the size and style of head being much at variance. It seems hardly desirable for us to have two kinds of heads of screws to meet the different needs of our machinery manufacturers. At the same time these proportions recommended would come far from what we should consider a proper size or style of head at the Brown & Sharpe Manufacturing Company.

74 It has already been suggested in the written discussion that this style is not the best we know of; that a flat head screw with rounded corners is better in many ways. This came up for discussion at the Scranton meeting, and I there presented some arguments explaining the advantages of the style of screw I am recommending in considering the paper presented by Mr. Reist.

75 Such a style of head[1] does not require as great care in counterboring, because the counter-bored hole does not have to be as uniform in depth to make a good appearance of the screw. This style of screw can, in many cases, take the place of the style shown on page 36, the round-headed machine screw. This form of screw head that I recommend was used many years ago, and perhaps originated at the Pratt & Whitney works. For the last eighteen or twenty years the Brown & Sharpe Company have used it with satisfactory results.

76 At the Scranton meeting I was talking with Mr. Fred. J. Miller regarding this matter of screws, and he questioned why the flatheaded screws shown on page 37, which are often used with an oval top, were not made in the same style as the fillister screw with the rounded corners just recommended.

77 In discussing the matter with our experts after returning home, all the arguments seemed to be in favor of doing so. We have made the change so that the screw now, when in place, has the appearance of the fillister head screw.

[1] In the "American Machinist," January 11, 1906, p. 59, an article appears giving data and illustrations.

78 The diameters of heads, as shown in this paper, are also subject to the criticism that no constant is used in proportioning them; besides, the sizes are much too large for the requirements of machine tool work. The use of a smaller multiplier and a constant would bring them in good proportion.

79 It has been suggested that to make the head nearly twice the diameter of the body is too large for the flathead screws, and this accords with our experience.

80 It makes the head as large, as a wood screw head is ordinarily made by American manufacturers, and it does not seem that metal work would require so large a head as in woodwork.

81 In conclusion, I would say that it is a good plan to have a standard adopted, and the completeness of this report shows that much thought has been given to it by the Committee. Further investigation may lead us to see the reasons for some of these questionable recommendations, but it does not seem that the matter should be settled at this meeting, but should be held over until we have had a further opportunity to investigate and discuss it.

DISCUSSION

MAY, 1906

MR. S. D. BURLINGAME Since the December meeting of the Society, at which questions were raised as to the practicability of some of the points of this Report, I have given further consideration to the matter, discussing it both with members of the Committee and with others having large business interests in this matter.

Following are the points that still seem to be questionable:

FORM OF THREAD

83 Too sharp for small sizes of screws when flattened only $\frac{1}{8}$ in. As a suggestion, the threads might be flattened $\frac{1}{6}$ in. for sizes to $\frac{1}{4}$ in. diameter and $\frac{1}{8}$ in. for sizes above $\frac{1}{4}$ in. Even when the screw is flattened as much as $\frac{1}{6}$ in. for sizes to $\frac{1}{4}$ in., there is none too much clearance for the wear and variation of the tap, even when the tap is made approximately sharp; *i. e.*, with a corner of the thread just taken off sufficiently to insure a good cutting edge.

DIAMETERS

84 The series of diameters given in Table 1 are not in a regular progression of sizes. They do not match the American Screw Company's standard or any other standard that we know of and would

require new sets of taps to be carried by all the tap makers. The standard established by the American Screw Company and recently published by them was, as far as we know, the first in use and most others have followed it closely. If selected sizes from their list were used, keeping approximately to their standard for pitch diameter, making the outside diameter to whatever it would figure for the required amount of flattening, then the new set of screws would interchange with those already in use and there would seem sufficient reason for sizes to vary from a true progression. If, for some reason, this cannot be done, it would seem better to break entirely away from the old sizes and establish the new ones in a uniform geometrical progression, a standard that would appeal to the public as being ideally correct and thus have sufficient reason for existing to warrant the addition of another standard to the many with which we are already burdened.

85 Another good suggestion that has come to my notice is to adopt fractional sizes, thus partially avoiding the confusion of mixing screws and taps of different systems when sold in the market. I believe this has already been brought to the attention of the Committee.

BASIC STANDARD REFERENCE GAGES

86 In the Brown & Sharpe practice these are made by working to the Screw Thread Micrometer Caliper and include the Reference and Workman's Gage. The Workman's Gage is used to set an adjustable "Template Thread Gage" for testing screws. All these gages would be proved from the Screw Thread Micrometer Caliper, which would also be used to measure screw threads on the pitch diameter.

87 It would seem that a description of the use of the screw thread micrometer caliper for originating and maintaining standards should be a part of the report but as the Committee has not thought best to include it, the suggestion of a member of the Committee might be carried out, of cutting out the description of the Ball End Micrometer and not going into any particulars as to the methods of measuring.

88 In a conference that Mr. E. H. Neff and I had with representatives of the Committee after the meeting in New York, we understood that they had doubts as to the accuracy of measuring with the screw thread micrometer as an instrument to originate and maintain standards and that these doubts were based on the difficulty of producing exactly an angle of 60° on the measuring surfaces; also that the measuring point is in the next thread space—or rather half

a thread space—to the one covered by the V and that there might be a difference from the fact that the V straddled two sides of one thread and the sharp point half of one side of the same thread and the opposite side of the next thread. It would seem to us that such a contention is a matter of opinion and of the ability of the manufacturer of the gage to turn out good work rather than a discussion of the merits of the theory of the instrument.

89 Regarding the question of wear in a screw thread micrometer when great accuracy is required, calipers can be preserved "for reference only," the same as in the case of any other precision tools and others used for everyday work. Every such Caliper has in itself the means of testing in a large measure its own inaccuracy. The fact that the Brown & Sharpe Manufacturing Company is ready to stand back of this method of producing standards requiring a high degree of accuracy, seems a sufficient answer to these expressed doubts. It is the invention of the screw thread micrometer that has made possible the present advance in accurate measurement of screw threads.

PROPORTION FOR HEADS

90 In the "American Machinist" of January 11, 1906, is a good statement of the arguments favoring a head of about the proportion and style used by the Brown & Sharpe Manufacturing Company. It certainly seems that the style of fillister head screw with flat head and rounded corners should have a place in the report, as it has such decided advantages in appearance and utility over the styles shown.

SLOTS FOR SCREW DRIVER

91 There has been, for many years, a standard in use for the width of slots for screws based on the American Standard Wire Gage sizes, such a list being published in the Brown & Sharpe catalogue. These cutters are in very extensive use and are made by many other manufacturers of cutters besides Brown & Sharpe. The sizes are such as could just as well be used without the establishment of a new size.

Mr. EDGAR H. BERRY The Committee proposes a shape for the thread of the screw which is identical with the U. S. Standard form, with the single exception that the flat at the bottom of the thread of the screw is $\frac{1}{16}$ instead of $\frac{1}{8}$ of the pitch. It also recommends that the flat at the bottom of the thread of the tap shall be $\frac{1}{8}$ of the pitch, and we may infer that this difference in shape is considered necessary in order to provide a clearance.

93 Such a difference would be warranted if the tapped hole were an exact reproduction of the tap, but every tap user knows that in ordinary tapping the drilled hole must always be appreciably larger than the root diameter of the tap. A tap whose root diameter is equal to or greater than the diameter of the hole, can be coaxed through by advancing a little, then backing out, and so on, or it can be forced through at the imminent risk of breaking the tap, and with the certainty that a badly torn thread will be produced.

94 I believe that the flat at the bottom of the thread of the tap should be $\frac{1}{8}$ of the pitch as recommended by the Committee, but that the flat at the bottom of the thread of the screw should be the same size, and that a minimum limit should be fixed for the size of the hole before tapping. This hole should be large enough to give the necessary clearance at the root of the thread of the screw. The writer has tabulated figures from actual practice regarding the size of this hole, and he will be glad to place them at the disposal of the Committee.

95 By following this plan the standard thread for machine screws would be identical in shape with the U. S. Standard form. The subject of screw threads is surely sufficiently complicated now without introducing a new form. In addition to the U. S. Standard form, we already have the sharp V (which nobody can make, and which nobody even attempts to produce exactly), the old machine screw thread (of unknown and variable shape), the Whitworth thread, the Briggs pipe thread; the hose coupling thread (whose shape varies according to the accidental condition of a more or less worn or mutilated "sample"); and the metric thread, besides mongrel threads whose name is legion.

96 It has been said that the U. S. Standard form of thread does not provide clearance at the point and root. This is true if we assume that the originators intended to use the same shape for the bolt and nut, but as a matter of fact their report gives no dimensions whatever for the thread in the nut. At the time that this report was made the facilities for making close measurements were very limited, and the desirability and possibility of fixing definite clearances for mating parts was not generally recognized. The report in question does state that the nominal diameter applies to the bolt, and it seems a fair inference that the shape of thread also applies to the bolt, and that it was the intention that clearance should be provided in the nut as necessary.

97 Aside from the advantage of not introducing a new form of thread, the use of the U. S. Standard form has the additional advan-

tage that it weakens the screw less than the proposed form. This is a matter of considerable importance in small screws, as the pitch becomes relatively coarser as the diameter decreases. To illustrate the relative weakening effect of the two forms of thread let us consider the 0.070-72 screw, for which the diameter at root of thread would be 0.05196 with threads of U. S. Standard form, and 0.05045 (not 0.05046 as stated in the report) for threads with $\frac{1}{16}$ flat at root.

98 The bearing area of the threads would be identical in both cases, as the outside diameter of the screw, and the inside diameter of the hole in the nut remain unchanged. The latter is fixed by the size necessary for tapping, and the tap will be identical for both screws.

99 The resistance to stripping the thread by shearing it off at the root would be in the ratio of 0.05196 to 0.05045 or as 103 to 100, or 3 per cent in favor of the U. S. Standard form.

100 The resistance of the screws to tension would be in the ratio of $(0.05196)^2$ to $(0.05045)^2$ or as 106 to 100, or 6 per cent in favor of the U. S. Standard form.

101 The resistance of the screw to twisting (probably the most important consideration in a small screw) would be in the ratio of $(0.05196)^3$ to $(0.05045)^3$ or as 109 to 100, or 9 per cent in favor of the U. S. Standard form.

102 Another practical consideration is the extreme minuteness of a flat of $\frac{1}{16}$ of the pitch, when dealing with fine threads. In the case of a screw having 72 threads per inch, this flat would be obtained by taking 0.00075 inch off of a perfectly sharp point. Roughly speaking, this flat would be the same as the flat at the point of an ordinary sewing needle, and the maintenance of such a flat on a metal cutting tool under ordinary working conditions would certainly be a difficult matter. With the U. S. Standard form of thread this flat would be doubled, the bearing area of the thread would remain unchanged, and the screw would be strengthened in every other particular.

103 As the actual difference between the two forms of thread is so small when expressed in fractions of an inch, the calculations given above in regard to the relative strength of the screws may perhaps be criticised as having no practical value. It must be borne in mind, however, that a flat acts practically like a fillet, and it is a matter of common experience that doubling the size of a fillet may give an increase in strength which is out of all proportion to the actual amount of metal added.

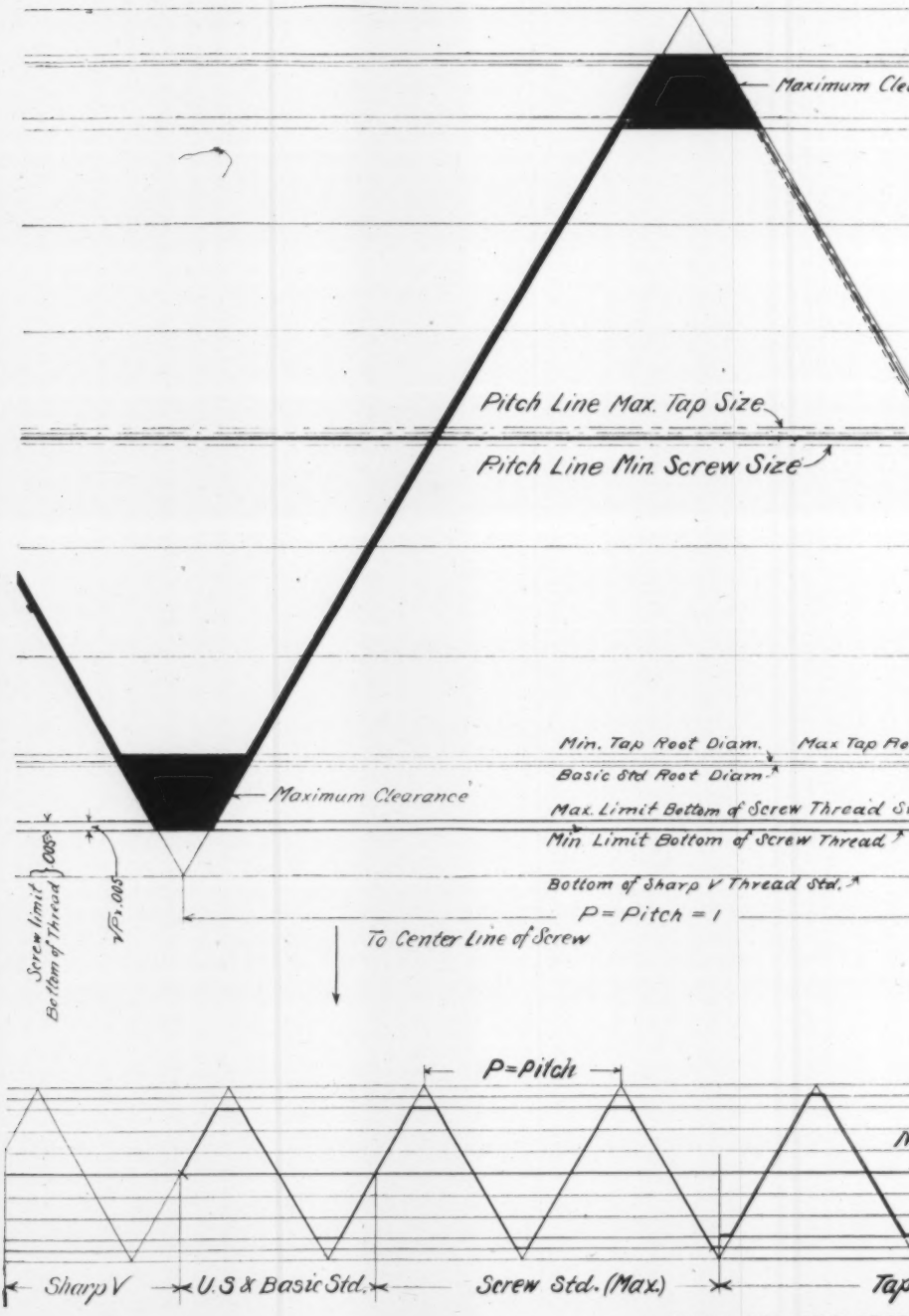


FIG. 5 RELATIVE PROP

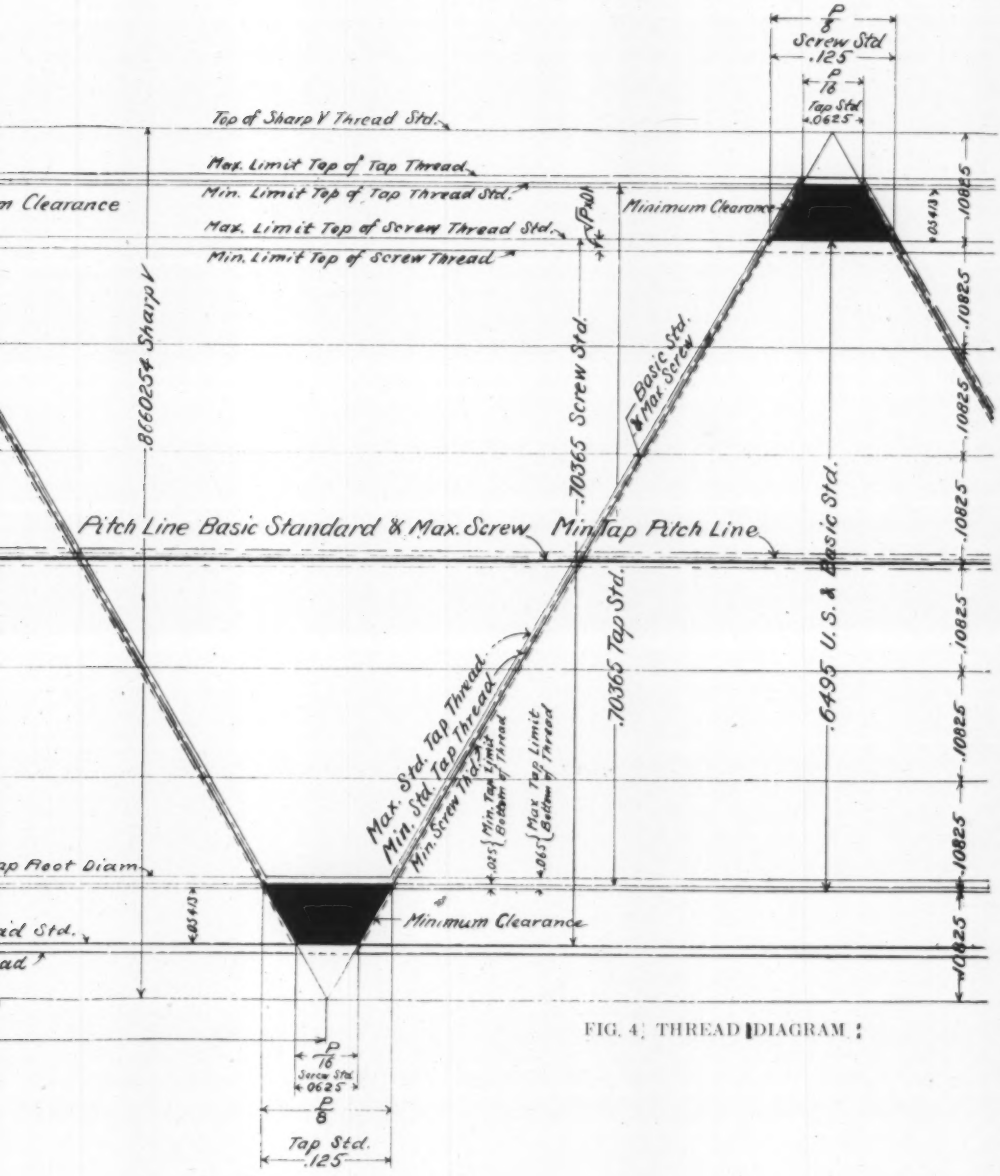
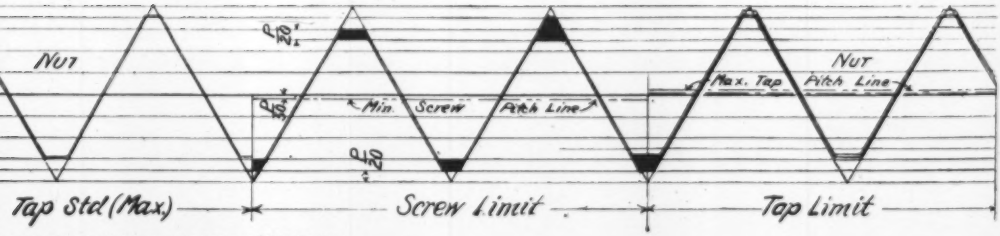


FIG. 4. THREAD DIAGRAM



PROPORTIONS VARIOUS THREADS

104 The writer has found that the impression prevails in some quarters that the Committee has recommended the U. S. Standard form of thread for the screw. This is probably due to the fact that the proposed Basic Standard Reference Thread Gage has a thread of U. S. Standard form. The Committee, however, does not recommend that the screw be made like this gage, but recommends that the screw be made like the gage shown on p. 5 of its report, which has a flat of $\frac{1}{16}$ of the pitch at the bottom of the thread.

105 To follow the recommendations of the Committee, it would be necessary to have three standard reference gages for each diameter and pitch.

a A gage which has a thread of U. S. Standard form but which does not correspond either to the screw, to the tap or to the hole. (See p. 4 of the report.)

b A gage corresponding to the screw and differing from the first one only by a minute variation in the diameter at the bottom of the thread. This variation would run from .0015″ for a screw having 72 threads per inch up to .0068″ for a screw having 16 threads per inch. (See p. 5 of the report.)

c A gage representing the tap and differing from the first two both as regards the form of the thread and the pitch diameter. (See p. 6 of the report.)

106 By making the thread of the screw of U. S. Standard form, one gage would answer every requirement now met by the first two, thus making a saving of $\frac{1}{3}$ in the original cost of the reference gages with which the manufacturer would have to provide himself. For purposes of record and reproduction, it might, of course, be desirable to have an additional primary standard gage, but this would not necessarily have to be in the possession of every manufacturer, and, in any event, it might as well be identical (excepting for appearance and marking) with the Standard reference gage for screws.

107 It would surely be most unfortunate if the Society should set the seal of its approval on any system of screw threads which introduces an entirely new form of thread. And the adoption of the particular form recommended would be specially undesirable, as it differs only slightly, and for no apparent reason, from the well established U. S. Standard form, which has given excellent service in those particular diameters and pitches for which it has been generally used for over 40 years.

VENTILATION OF THE BOSTON SUBWAY[1]

By HOWARD A. CARSON, BOSTON, MASS.
Non-Member

1 The following paper or statement has been prepared somewhat hastily at the request of the Society. A considerable portion of the text has been taken, with but little change in language, from reports by the writer to the Boston Transit Commission and nearly all of the pictorial illustrations have been taken from the same reports.

2 The aggregate length of the Boston Subway system is about 3½ miles and may be conveniently divided, for purposes of description, into the original subway, the East Boston tunnel, and the Washington street tunnel. Most of the subway system is for two tracks, but a portion of the original subway is for four tracks.

3 The original subway and the East Boston tunnel were intended for surface electric cars running singly, but two of the tracks in the subway have been for some years used for trains, contrary to the former wishes of the Transit Commission. The Washington street tunnel is intended solely for trains, and on its completion the trains will be taken from the original subway and the subway be restored to its former use, *i. e.*, for surface cars run singly.

4 The general scheme of ventilation in all parts of the system is that fresh air shall enter at the stations or portals and be drawn out from what may be called the traffic tubes at points midway between the passenger stations. Owing to the respective environments of (1) the original subway, (2) the East Boston tunnel and (3) the Washington street tunnel, the conduction of the air after leaving the traffic tubes in these three divisions varies. Some description and illustration of the methods adopted in the ventilation of these divisions will presently be given. Before doing so, however, it may be well to give some indication of the density of passenger traffic. Some idea of this may be had by examining the following figures regarding total number of passengers per annum, going and coming, at the most important station of the original subway and at eight important steam railroad passenger stations, as taken from the report of the Transit Commission for the year ending August 15, 1899:

[1]To be presented at the New York meeting (December, 1906) of the American Society of Mechanical Engineers and to form part of Vol. 28 of the Transactions.

Station	Number Passengers
St. Louis Union Station, St. Louis	8,000,000
Grand Central Station, New York City	14,000,000
South Union Station, Boston	21,000,000
North Union Station, Boston	23,108,384
Broad street Station of North London Railway	27,000,000
Park street Station of the Boston Subway	27,400,000
Waterloo Station, London (1898)	28,659,118
St. Lazare Station of the Chemin de fer de l'Ouest, Paris	43,062,688
Liverpool street Station of the Great Eastern Railroad, London	44,377,000

The Park street station figures are based on the traffic during the eleven months ending August 15, 1899 (before the introduction of trains), and are estimated from the sale of tickets and from other observations.

6 It was estimated that at least 50,000,000 passengers used the original subway during the first 12 months after its completion. Its use has apparently increased since then over 60 per cent.

VENTILATION OF THE ORIGINAL SUBWAY

7 In the original subway there are ventilating chambers placed at the side of the tunnel, midway between each pair of stations, and exhaust fans are set in circular openings in the walls that separate the chamber from the traffic tubes. (Fig. 1.) The air which enters at the stations is drawn by the fans from the tunnel and discharged vertically from the chambers, in some cases through grated areas in the street sidewalks and in other cases through low shafts. Some details concerning two of these ventilating sections, which will serve to illustrate the method of ventilating the original subway, follow.

8 The section between the Park street station and the Boylston street station is 4-tracked, its interior width being 48 feet and its height from the base of the rails to the under side of the roof 14 feet 8 inches. The distance between the centers of the stations is about 1250 feet. The ventilating chamber for this section is under Boston Common, nearly opposite West street and midway between the stations. (See Fig. 2.) Fig. 3 shows the low stone building, which serves as a shaft, over the chamber. This section is ventilated by two fans, each having a diameter of eight feet and a rated speed of about 175 r. p. m. The rated delivery of each fan is 37,000 cubic feet per minute.

9 The section between Park street and Scollay square is double tracked, its interior width being 23 feet and its clear height, from the base of the rails to the tie-rods, 14 feet 8 inches. The distance between

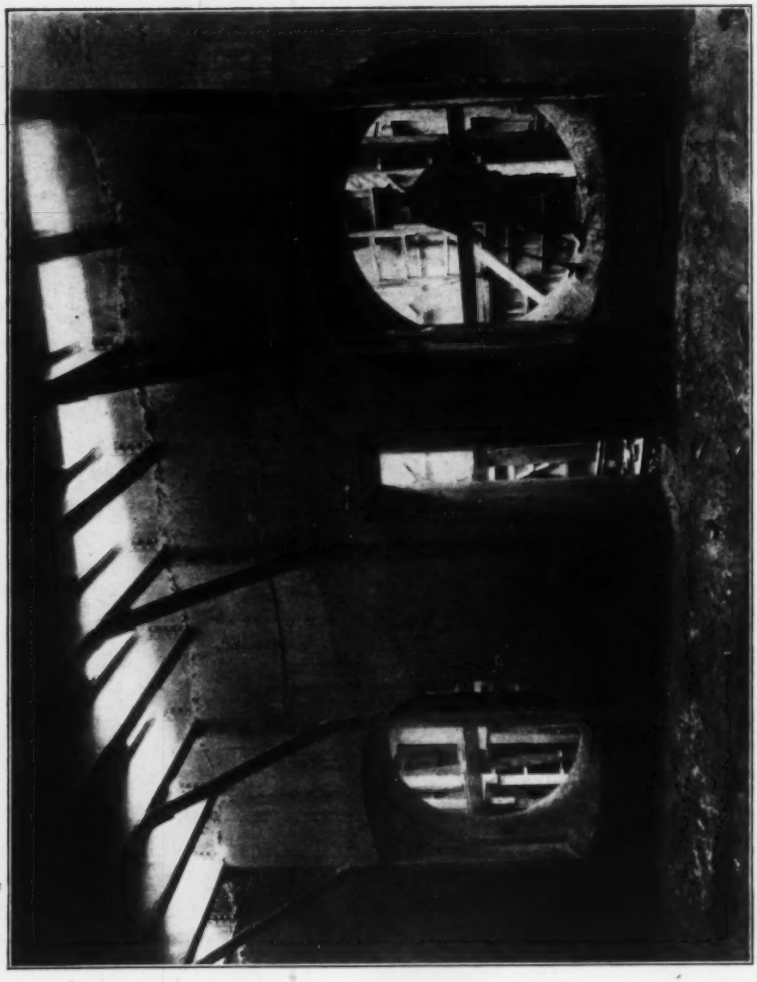
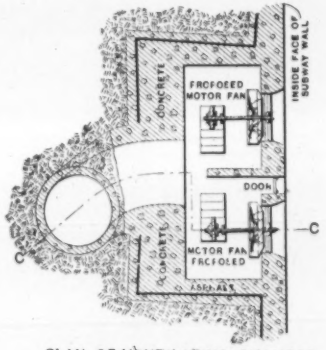
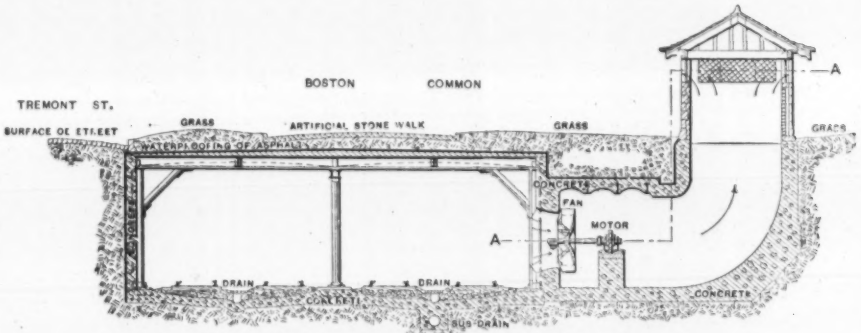


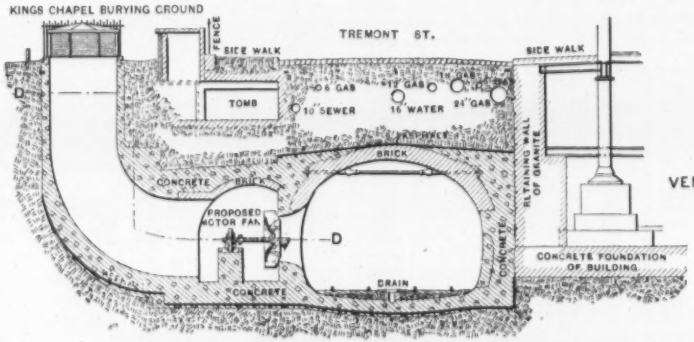
FIG. 1 FAN OPENINGS AND DOOR FROM SUBWAY TO VENTILATING CHAMBERS



PLAN OF VENTILATING CHAMBER
SECTION ON LINE D D.



FOUR TRACK SUBWAY AND VENTILATING CHAMBER
NEAR WEST ST.
SECTION ON LINE B B.



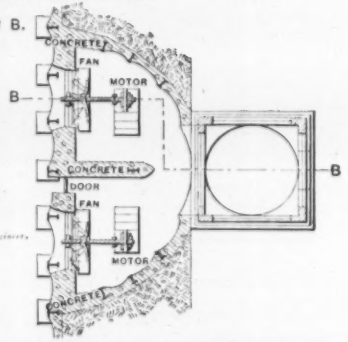
TWO TRACK SUBWAY AND VENTILATING CHAMBER
NORTH OF SCHOOL ST.
SECTION ON LINE C C.

PLATE 2

PLANS AND SECTIONS
OF TWO
VENTILATING CHAMBERS

SCALE
12 in. 0 2 4ft. 6 8 10 ft.

H.A. Carson Chief Engineer.



PLAN OF VENTILATING CHAMBER
SECTION ON LINE A A.

FIG. 2 VENTILATING CHAMBER IN BOSTON COMMON

the centers of the stations is 1450 feet. The ventilating chamber is situated under the Kings Chapel burying ground, a little to the north or midway between the two stations. (See Fig. 2.) The shaft shown in Fig. 4 has an exterior intended to render it inconspicuous. The two fans which serve this section are seven feet in diameter, and have a rated capacity of 24,000 cubic feet per minute each at 220 r. p. m. With rates as stated, the air would be changed in these sections about once in ten minutes. The stated frequency of change, is six times as great as that reported to have been provided for in the most recent London subway, the Baker street and Waterloo Railway.

FIG. 3 SHAFT OVER VENTILATING CHAMBERS

10 A photograph of a grated outlet over the ventilating chamber at the corner of Washington and Hanover streets is shown in Fig. 5. An inspection of this photograph indicates an obvious objection to an outlet of this class.

VENTILATION OF THE EAST BOSTON TUNNEL

11 The general scheme of taking in fresh air at the stations and portals and discharging from the traffic tubes at midway points is observed in the East Boston tunnel. But as it was, of course, not practicable to discharge directly into the outer air from the middle of the harbor, provision was made to conduct the vitiated air to the shores.

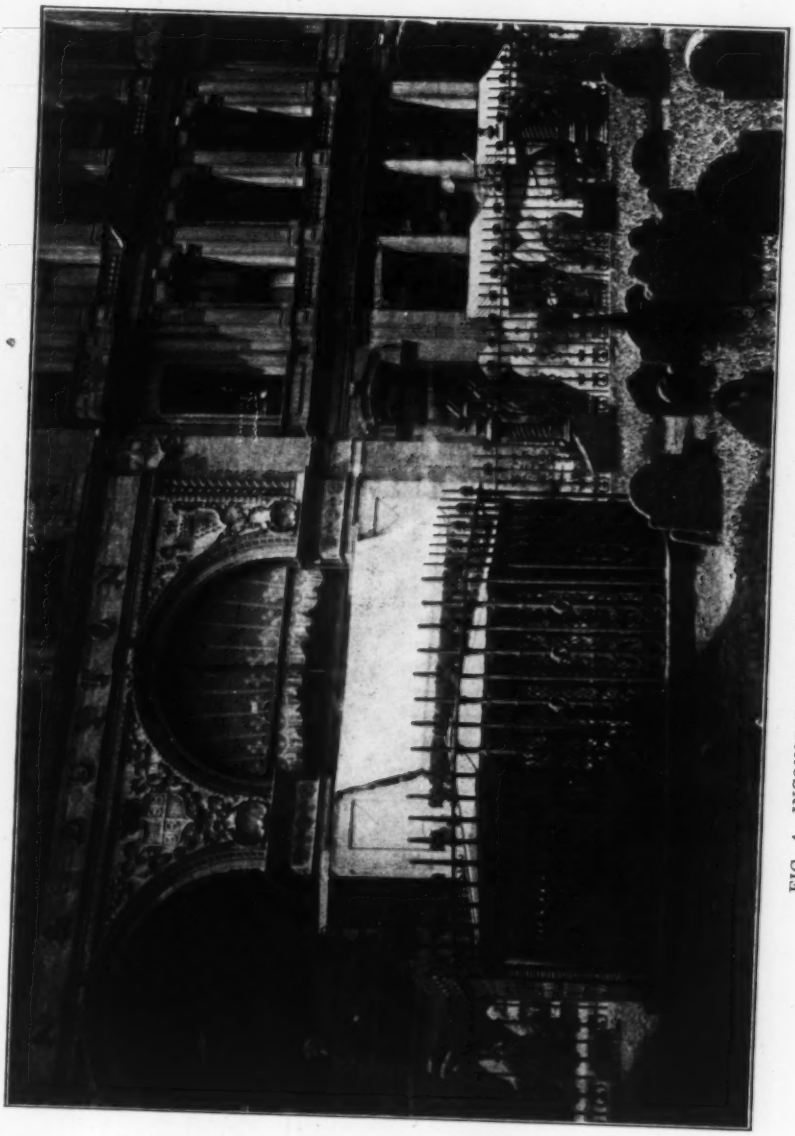


FIG. 4 INCONSPICUOUS SHAFT OVER VENTILATING CHAMBERS

FIG. 5 GRATED OUTLET OVER VENTILATING CHAMBER

12 The duct used in ventilating the harbor portion of the tunnel extends from near Webster street in East Boston to and under the harbor and to the Atlantic avenue station. The duct (see Fig. 6) has a cross-section of about 48 square feet, and is formed in the upper part of the tunnel by means of a diaphragm, one inch thick, made of expanded metal enclosed in cement mortar. This diaphragm is attached to the tunnel walls by steel rods and plates which are themselves encased in concrete. A partition midway between its two ends divides the duct into an easterly and a westerly portion. Immediately on each side

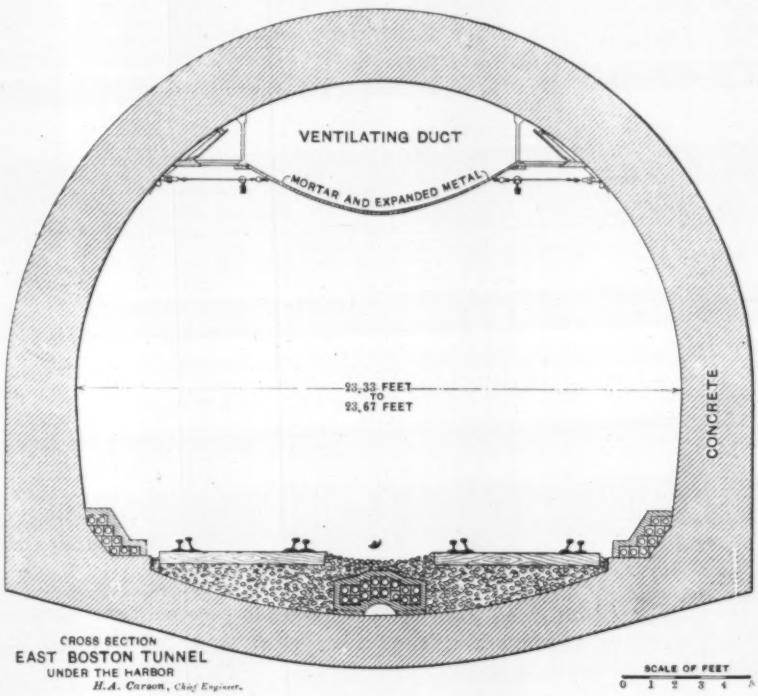


FIG. 6 VENTILATING DUCT

of the partition there are 14 openings, each 4 feet long and 1 foot 5 inches wide, through the flat portion of the cross-section of the duct; and at intervals of about 550 feet there are other groups of openings, diminishing in number as they approach the fan chambers. These openings are fitted with doors which can be opened or closed from the tunnel below. When the movement of the air in the tunnel is not affected by wind only the two groups of openings close to the middle partition are kept open. When, however, the movement of

the air is so affected, the various openings should be used in such a manner as to best promote the even ventilation of the different parts of the tunnel.

13 Fresh air enters the tunnel from the portal at East Boston and also from and through the station near Atlantic avenue, distant about one mile from the portal. This air moves to near the middle of the tunnel under the harbor and passes through the openings into the duct referred to above. The air is then drawn to the east and west and leaves the tunnel at the fan chambers at Lewis street in East Boston and at Atlantic avenue, respectively. A diagram rudely indicating the movement of the air is given in Fig. 7.

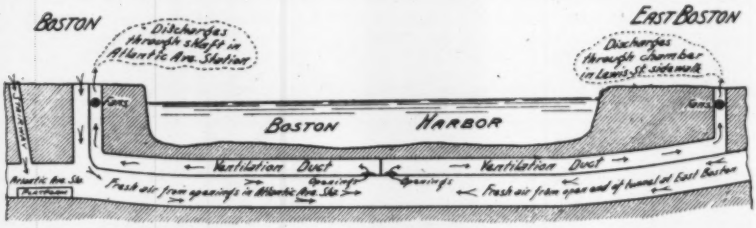


FIG. 7 DIAGRAM (NOT TO SCALE) INDICATING MOVEMENT OF AIR
THE LENGTH OF TUNNEL INDICATED IS ABOUT ONE MILE

14 In the East Boston chamber the air leaves through a grated area 40 feet long and 7 feet 1 inch wide, in the sidewalk. It is intended that the air shall not pass through any part of the gratings of this and other sidewalk outlets at a velocity greater than 3 miles per hour.

From the Atlantic avenue chamber the air passes into a divided duct carried up at one end of the passenger station and is discharged 21 feet above the surface of the street.

15 The ventilating apparatus at the East Boston chamber consists of two single-inlet 8-ft. vertical fans having for normal and maximum speeds, respectively, 175 and 185 r. p. m. and at the Atlantic avenue chamber, two double-inlet 7-ft horizontal fans with speeds of 205 and 218 r. p. m. At the maximum speeds stated the two fans in each chamber, with an input of about 12 horse power to each fan motor will together exhaust 45,000 cubic feet of air per minute—90,000 cubic feet for the two chambers.

This quantity will give an air velocity in the tunnel of nearly $2\frac{1}{2}$ feet per second and will change the air in the section of the tunnel

under the harbor every 15 minutes. Smaller air deliveries can be obtained by running the fans at lower speeds or by running one fan at a time in each chamber.

16 The portion of the East Boston tunnel between the Atlantic avenue station referred to above and Scollay square—the westerly end of the tunnel—is ventilated by means of fans placed in horizontal openings over the roof of the subway and the air is discharged through a chamber connecting with a grated opening in the sidewalk, nearly opposite the Custom House. The two fans, with an input of about 3½ horse power to each fan motor, will each exhaust 20,000 cubic feet of air per minute which will give an air velocity in the tunnel, toward this centrally placed chambers of one foot per second and change the air in 1600 feet length of tunnel in 13 minutes.

THE WASHINGTON STREET TUNNEL

17 As in the original subway and in the East Boston tunnel, fresh air is to be admitted at the stations and portals and withdrawn from the traffic tube at about midway points. It is not in general practicable to discharge the vitiated air directly into the outer air at the points where it is taken from the traffic tubes; nor is it practicable to discharge through grated areas in the sidewalks, the latter during the day being densely crowded. Air admitted at the portals and at the station entrances and leaving the tunnel at intermediate points will pass thence through specially constructed ducts—in some cases underneath and in others above the tunnel—having a minimum cross-sectional area of about 40 square feet and a length of from 270 feet to 430 feet, to fan chambers. There will be room in each chamber for two single-inlet centrifugal fans, each with a capacity of 20,000 cubic feet or more per minute, giving an average velocity of air in the tunnel of upwards of one foot per second, equivalent to changing the air in each section, say three times every hour.

18 The general movement of the air in the Washington street tunnel is shown in Fig. 8.

19 For specific illustration we may take the platform at LaGrange and Boylston streets. This is 350 feet long and has 15 feet of breadth of stairway at one end and 18 at the other. Air entering the Boylston street station will reach the platform through a stair and passageway. Turning southerly, it will pass through the tunnel to Eliot street, a distance of about 530 feet from the Boylston street entrance. It will be joined at LaGrange street by a current of air from the entrance and stairway there located and at Eliot street

by a northerly current admitted to the tunnel at the southerly portal, 570 feet farther south. At Eliot street the combined volume will pass through openings in the westerly side of the tunnel into a duct below the tunnel invert. This duct, about 370 feet long, will lead the air back, northerly, to and underneath the LaGrange street station, where the air will be extracted by fans and discharged at the back of the station through a shaft having a clear cross-section of 36 square feet and carried to the height of the adjacent buildings.

20 It may be mentioned here that practically all of the stairways and station entrances and exits on the Washington street tunnel are on what was formerly private property which has been taken by the Transit Commission and that all but one of the fan chambers and exits for so-called soiled air will also be on what was formerly private ground. The one exception is in the middle of Adams square. The discharge in that case will be through a grated opening around the Adams monument.

21 The following table gives additional details of the courses of the ventilating currents of air at various points in the Washington street tunnel.

1 AT LaGRANGE STREET STATION

INLETS FOR FRESH AIR	COURSE OF AIR IN TUNNEL	COURSE OF AIR IN DUCT
South portal. LaGrange street entrance. Boylston street entrance.	Northerly, from south portal to invert duct inlet at A on Fig. 8; about 570 feet. Southerly, from Boylston street station entrance to A; about 530 feet.	From A, northerly under tunnel invert and westerly under LaGrange street station to fan chamber and chimney at LaGrange street station; about 370 feet.

2 AT HAYWARD PLACE STATION

INLETS FOR FRESH AIR	COURSE OF AIR IN TUNNEL	COURSE OF AIR IN DUCT
Essex street entrance. Hayward place entrance. Temple place entrance. Winter street entrance.	Northerly, from Essex street station entrance to arch duct inlet at B on Fig. 8; about 650 feet. Southerly, from Winter street station entrance to B; about 650 feet.	From B, southerly under tunnel arch and easterly under Hayward place station, to fan chamber and chimney near Hayward place entrance; about 430 feet.

3 AT OLD SOUTH MEETING HOUSE STATION

INLETS FOR FRESH AIR	COURSE OF AIR IN TUNNEL	COURSE OF AIR IN DUCT
Summer street entrance. Franklin street entrance. Old South Meeting House entrance. Water street entrance. Old State House entrance.	Northerly, from Summer street station entrance to arch duct inlet at C on Fig. 8; about 550 feet. Southerly, from Old State House station entrance to C; about 900 feet.	From C, northerly under tunnel arch to fan chamber and chimney near Old South Meeting House entrance; about 270 feet.

4 AT SURFACE IN ADAMS SQUARE

INLETS FOR FRESH AIR	COURSE OF AIR IN TUNNEL	
Old State House entrance. Two entrances between Hanover street and Haymarket square. North portal.	Northerly, from Old State Station entrance to fan chamber and surface grating at D on Fig. 8; about 300 feet. Southerly, from north portal to D; about 1430 feet.	No duct.

THE VENTILATION OF ELECTRIC SUBWAYS

22 Most of the subways hitherto constructed have not been provided with mechanical plants for positive ventilation. The reason of this doubtless is that the air in electrically operated subways without ventilation is, in general, far better than that of steam operated subways that are ventilated. Professor S. Homer Woodbridge states that: "A locomotive burning 35 pounds of coal per mile of run produces at a running rate of 15 miles per hour about the same quantity of carbonic gas and of water-vapor as 22,000 average adults in a state of repose, besides emitting an indefinite, though troublesome if not dangerous, amount of smoke, and sensible traces of carbon monoxide and sulphurous gases, to still further vitiate the air. If steam locomotives were to be used in the subway, probably at least 30 times as much fresh air would be required to ventilate it as with electric propulsion."[1]

23 The following table comparing the relative vitiation of the air In the subway at a time when the traffic was large and when no fans

[1]First Annual Report of the Boston Transit Commission, p. 43, for the year ending August 15, 1895.

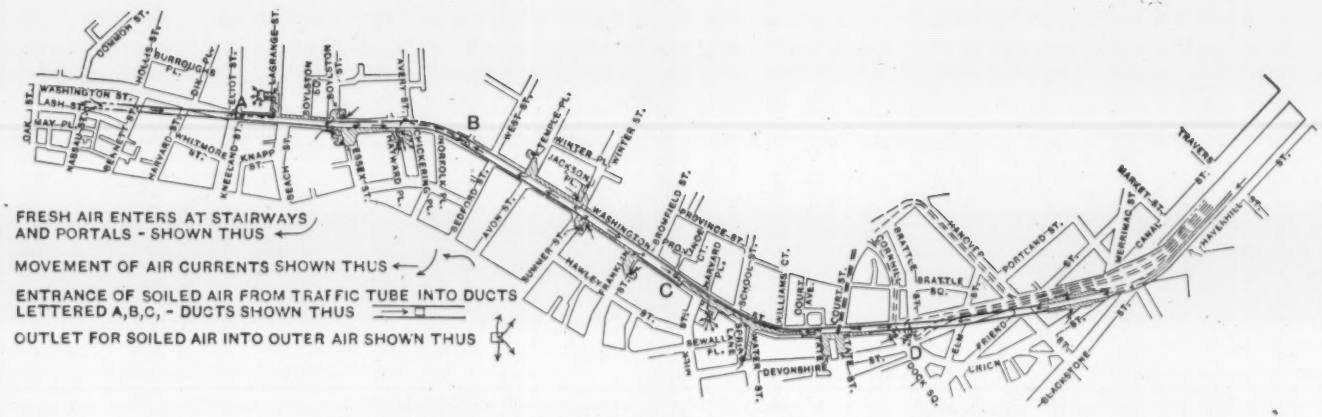


FIG. 8 GENERAL MOVEMENT OF AIR IN WASHINGTON STREET TUNNEL

were running and that in various halls, theaters, churches, schools, etc., appears to justify the omission of positive ventilation in subways.

	Parts of Carbon Dioxide in 10,000 Volumes	Remarks
Boylston street station, 5 feet above southbound platform	9.45	Samples taken between 5 and 5.30 p. m., on week days in January and February, 1899. One of the fans in the West street chamber is believed to have been running when the third sample was taken. In the other cases none of the fans were running.
Midway between the Boylston street station and the Winthrop school ventilating chamber	6.53	
Park street station, 5 feet above the southbound platform	7.78	
Adams square station, 5 feet above platform	6.62	
Haymarket square station, 5 feet above northbound platform	9.13	
On the street in the central part of the city	4.5 to 5.9	Made at about the same time of year.
In the center of a car on Boylston street about to enter the subway	24.97	Sample taken about 8.30 a. m., February 25, 1899, and car contained about sixty-five passengers. Rear door was opened once or twice while sample was being taken. Forward ventilator was closed and rear ventilator open about one-half inch. Weather clear and cold.
City Hall Council Chamber, two-thirds full	Floor 10.12 to 14.60 Gallery 13.22 to 18.58	
Large public hall in Boston, near open door, with in-draught	13.93	
Another hall in Boston, well-filled	32.59 to 36.43	(the latter being in the gallery).
Four of the principal theaters in Boston	16.16 to 48.7	
Two large churches, Boston and Brookline	12.45 to 18.19	
Twelve schools in Boston, Cambridge, Chelsea, etc.	7.1 to 23.50	

24 The fitness of air in the subway for breathing, however, can probably be better ascertained by means of sensitive noses of persons used to fresh air than by the ordinary methods of chemists. Crowded unventilated subways contain not only carbonic acid and other matters thrown off from human lungs but have also, widely diffused through the air, fine dust from the ballast, fine particles of oil from the machinery, and finely ground particles of iron from the brake shoes. All of these are disagreeable and probably injurious to health.

25 Another matter, at times perhaps more disagreeable and injurious than either of the foregoing, is that of the rise of temperature in subways caused by the conversion of a large amount of electric energy into heat. As far as the writer is aware, no particular attention had been given to this question until the summer of 1905 after the opening of the New York subway. The most obvious remedy for annoyance caused by the fine dust, iron, and oil, and the rise of temperature referred to, is a judicious use of an ample ventilating system.

THE COST OF SUBWAY VENTILATION

26 A very rough estimate for the Boston system places the total cost of the ventilating construction, including chambers, ducts, fans and motors, at $125,000, or less than 1 per cent of the combined cost of the original subway, the East Boston tunnel, and the Washington street tunnel. An equally rough estimate of the cost of operation, including power, depreciation, attendance, and interest on first cost, for ventilating the combined system is $14,000 per annum. This will probably be less than 1 per cent of all costs of operation and interest.

The cost does not appear to be prohibitive, and considering experience up to the present time it seems fair to say that electric subways with dense passenger traffic should have the means, and the means should be freely used, for complete positive ventilation.

27 It may be well in closing to note that if the passengers in the subway are to breathe pure air the cars should be ventilated as well as the subway itself. The seventh observation in the table on the preceding page shows that the air in a car just about to enter the subway contained more than three times as much carbon dioxide as the average air above the station platforms.

FERROINCLAVE ROOF CONSTRUCTION[1]

By ALEXANDER E. BROWN, CLEVELAND, OHIO
Member of the Society

1 On December 17, 1900, the entire shops of The Brown Hoisting Machinery Company were destroyed by fire. This destruction was complete as to floor, as well as to roof of the building. The fire started in the erecting, or assembling shop, which was constructed with brick walls and steel columns and roof trusses, the only wood being the roof purlins, which were 8 x 12 surfaced pine timbers on which surfaced, matched roof boards were secured. The roof proper consisted of the best slate laid on a covering of asbestos paper on the roof boards. All of the roof boards and purlins were painted with a so-called fire-proof paint. The floor of this, as well as of all of the rest of the buildings connected with it, were of three inch jointed plank laid on two feet of cinders on the ground.

2 All of the buildings were one-story construction, 50 feet high at the ridge, uniformly 100 feet wide and without galleries, which construction was considered by the insurance companies at the time as practically fire-proof and the lowest rate of insurance was accorded to it. A barrel of shellac varnish outside of the building, in a corrugated iron shed, suddenly caught fire, exploded, and blew in one of the outside windows of the erecting shop, carrying a volume of flame and gas into the upper part of the building next to the roof boards, which immediately caught fire and burned. The fire spread with such rapidity that the entire shop buildings, covering five acres, were completely destroyed in less than forty-five minutes. The roof itself, having caught from the under side, seemed to form an immense reverberatory furnace, as the floor of the building and all of its contents were burned from the reflected heat of the burning roof boards.

3 This building was considered by the insurance companies one of the best of manufacturing risks—but after the fire, the rates all over the United States were greatly increased on buildings of similar construction.

4 On account of the losses and detentions in business and the increased insurance risks, the company determined to rebuild the shops as nearly fire-proof as it was possible to design them. The

[1]To be presented at the New York meeting (December, 1906) of the American Society of Mechanical Engineers and to form part of Vol. 28 of the Transactions.

entire structure of the building was determined on to be built of steel, and the walls possibly of brick or concrete; but the roof and floor were not determined upon until after the structural work had been commenced, assuming that a good fire-proof roof could easily be obtained at any time. It was found, however, that any good fire-proof construction in the way of roof covering that was in use at that time weighed from 30 to 45 pounds per square foot. It was found that this additional weight of roof covering over the weight of a good slate or gravel roof would add to the cost of the entire building in structural work necessary to hold up the same about $50,000; and for this reason I determined that not more than fifteen pounds per square foot of roof should be used for the covering on the ordinary spacing of purlins of about five feet centers.

5 In my efforts to find a suitable roof of the proper strength within this weight and at the same time perfectly fire-proof, I felt that I would have to look to some form of cement steel construction. I

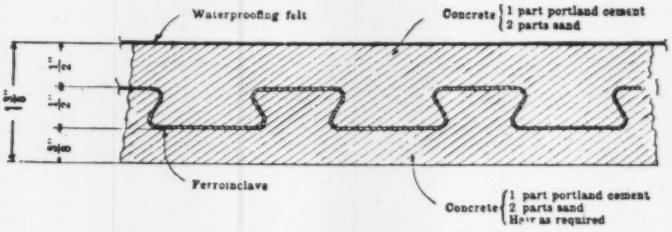

Waterproofing felt
Concrete { 1 part portland cement 2 parts sand
Ferroinclave
Concrete { 1 part portland cement 2 parts sand Hair as required

FIG. 1—SECTION OF FERROINCLAVE ROOF
AS USED ON SPAN 4′ 10½″ C. TO C. OF PURLINS

soon determined that if it were possible to make commercially sheets with dovetail corrugations that could be put on to the roof purlins the same as corrugated iron, and afterwards cemented top and bottom with a mixture of Portland cement and sand, the requirements as to weight and strength would be obtained. After some time of study, I was fortunate enough to devise a method for quickly and cheaply forming dovetail corrugations in a sheet of steel. This, however, was at first with parallel sides to the corrugations, which I found would not do, as they would not telescope and lap over one another in shingle fashion at the ends to make them water-proof before putting cement on them.

6 Shortly after this I devised another method by which the corrugations were made wider at one end of the sheet than at the other on one side, and the reverse on the other; that is, they were alternately wide and narrow on each end of the sheet, allowing either

end to telescope into either end of its adjoining sheet, making them shingle perfectly on the roof and forming a perfectly water tight roof without cement. The sheets were made so that the laps on the sides as well as the end laps would interlock so as to be water-proof. After some experimenting, it was found that with No. 24 soft steel sheets with the dovetail corrugations filled with cement mortar, two parts of sand and one of Portland cement, top and bottom of the corrugations, so that the total thickness of the metal and cement was from $1\frac{1}{4}''$ to $1\frac{3}{8}''$, the weight did not exceed fifteen pounds per square foot, and that the strength, on 4′ $10\frac{1}{2}''$ centers between purlins was such that the

FIG. 2 METHOD OF APPLYING CEMENT

covered sheets would sustain 60 pounds per square foot with a factor of safety of five. On tests made later on the same spans, 300 pounds per square foot just cracked the cement on the under side.

7 Ferroinclave, or iron in the form of dovetail, is the particular name by which this material is now known. After designing this material, on later investigations, I found that many attempts had been made in the past to utilize this very desirable form of corrugation for holding cement or other plastic material, both for shingles and other purposes, but all of them had been abandoned, apparently on account of the costly or imperfect methods used for the production of the corrugations, and also because they could not be made to shingle in order to make the roof water-proof of itself.

8 In the Ferroinclave, adjacent dovetails or corrugations are wider in their reverse directions sideways, the depths of the corrugations thus being parallel and uniform. The depth of corrugations, as ordinarily used and found best for the purpose, is ½″, and the sheets ordinarily are 10 feet long, and lay 20 inches wide on the roof. The laps on the purlins are usually three inches. The novel method of forming dovetail corrugations in sheet metal, as well as the article manufactured itself, known as Ferroinclave, were the subjects of patents obtained in this and various foreign countries.

9 In the use of the Ferroinclave, it is treated as the tension member, or bottom cord of the girder span it has to form, the cement only to act in compression.

10 The tables which follow of actual experiments made with No. 24 Ferroinclave sheets with different thicknesses of cement on top of same, with uniform thickness of plaster on the under side, gives center deflections for various loads up to the breaking load for each thickness of cement; and the diagram gives the thickness of cement required on top of the Ferroinclave sheets to produce ½ inch center deflection on spans of 4′ 10½″ for the different loadings per square foot shown.

11 The tests were all made upon sheets 20 inches wide, resting upon one inch square iron bars laid along the tops of I-beams and spaced 4 feet 10½ inches centers. All of the sheets were coated on the upper side with a mixture of two parts of sand to one part of Vulcanite cement and with a ⅜-inch mixture composed of two parts sand, one part cement and some hair below the corrugations on the under side. The sheets were then laid off into areas of one square foot each, and upon these areas were piled steel bars, so as to produce the given weight per square foot, as called for in the following tables. Deflection was taken at middle of sheet by means of a lever which multiplied the deflection eight times.

12 In comparing the diagram (Fig 3) with the actual tests made, it will be seen that where the curve starts on this diagram from the straight line, the thickness of sheet is not the most economical for the thickness of cement shown on the diagram beyond that point. A sheet of No. 22 Ferroinclave of five foot span covered with 4-inch cement over the top of corrugations, stood a breaking load of 3000 pounds per square foot, uniformly distributed, and is suitable for floors to be used up to 600 or 700 pounds per square foot. The gallery of the machinery floor of the Brown Hoisting Machinery Company's works is of this thickness of construction, and is used even up to 800 or 900 pounds per square foot.

TEST A

Upper side of sheet filled with cement to a thickness of one inch above corrugations.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
54 pounds	1/16 inch	328 pounds	7/16 inch
136 pounds	1/8 inch	365 pounds	3/4 inch
221 pounds	5/16 inch	402 pounds	3/4 inch
256 pounds	3/8 inch	439 pounds	15/16 inch
299 pounds	1/2 inch	476 pounds	1 1/4 inch

Sheet failed during application of increased load.

TEST B

Upper side of sheet filled with cement to a thickness of 1½ inches above corrugations.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
54 pounds	1/64 inch	402 pounds	11/32 inch
136 pounds	1/16 inch	439 pounds	3/8 inch
225 pounds	1/8 inch	476 pounds	13/32 inch
262 pounds	5/16 inch	513 pounds	1/2 inch
299 pounds	7/32 inch	550 pounds	9/16 inch
329 pounds	11/64 inch	587 pounds	25/32 inch
365 pounds	9/32 inch	624 pounds	1 5/16 inch
660 pounds		failure	

This sheet broke in the center of one of the spans by tearing the iron.

TEST C

With two inches of cement above corrugation on upper side.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
54 pounds	0 inch	476 pounds	7/32 inch
136 pounds	1/32 inch	513 pounds	1/4 inch
225 pounds	3/32 inch	550 pounds	9/32 inch
262 pounds	7/64 inch	587 pounds	5/16 inch
299 pounds	1/8 inch	624 pounds	3/8 inch
329 pounds	9/64 inch	659 pounds	27/64 inch
365 pounds	5/32 inch	694 pounds	1/2 inch
402 pounds	11/64 inch	729 pounds	5/8 inch
439 pounds	3/16 inch	764 pounds	1 1/4 inch
799 pounds		1 5/8 inch	

This sheet failed by tearing the iron before the increased load could be put on.

TEST D

With 2½ inches of cement above corrugation on upper side.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
225 pounds	1/16 inch	900 pounds	11/32 inch
450 pounds	1/8 inch	1125 pounds	13/64 inch
675 pounds	11/64 inch	1350 pounds	failure

This sheet broke in the middle of the span by tearing the iron.

TEST E

With three inches of cement above corrugation on upper side of sheet.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
225 pounds	1/32 inch	1125 pounds	13/64 inch
450 pounds	1/16 inch	1350 pounds	21/64 inch
675 pounds	3/32 inch	1575 pounds	not taken
900 pounds	5/32 inch	1800 pounds	failure

This sheet broke in the center of the span by tearing the iron.

TEST F

With 3½ inches of cement above corrugation on upper side.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
225 pounds	1/32 inch	1125 pounds	5/32 inch
450 pounds	1/16 inch	1350 pounds	7/32 inch
675 pounds	3/32 inch	1575 pounds	21/64 inch
900 pounds	1/8 inch	1800 pounds	not taken
1975 pounds	failure		

This sheet broke in the middle of the span by the tearing of the iron.

TEST G

With four inches of cement above corrugation on the upper side.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
225 pounds	1/32 inch	1350 pounds	11/64 inch
450 pounds	1/16 inch	1575 pounds	3/16 inch
675 pounds	5/64 inch	1800 pounds	1/4 inch
900 pounds	7/64 inch	2025 pounds	1/2 inch
1125 pounds	9/64 inch	2200 pounds	failure

This sheet broke in the middle of the span by tearing of the iron.

TEST H

With $4\frac{1}{2}$ inches of cement above corrugation on the upper side.

Load per Square Foot	Total Deflection	Load per Square Foot	Total Deflection
225 pounds	$\frac{7}{64}$ inch	1800 pounds	$\frac{5}{16}$ inch
350 pounds	$\frac{1}{8}$ inch	2025 pounds	$\frac{3}{4}$ inch
575 pounds	$\frac{3}{16}$ inch	2200 pounds	not taken
2375 pounds	failure		

Sheet broke in center of span by tearing the iron.

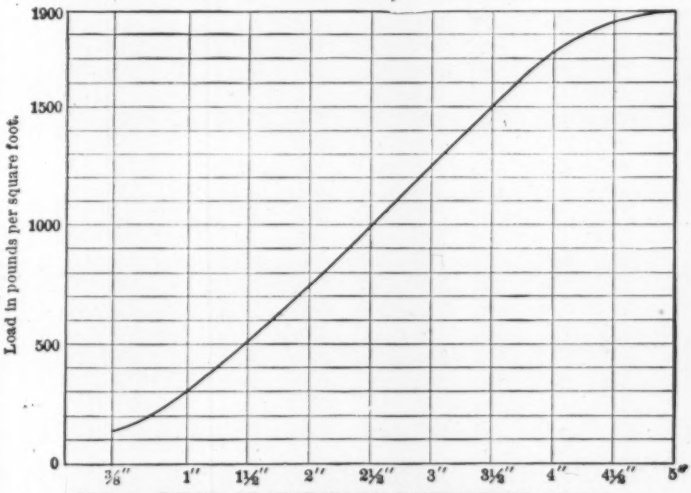


FIG 3 CURVE OF UNIFORMLY DISTRIBUTED LOADS

Per square foot, producing $\frac{1}{4}$-inch deflection on a 4 foot $10\frac{1}{2}$-inch span of No. 24 Ferroinclave, painted; then coated with cement, mortar and plaster. Time of setting, 14 days. Width of test pieces, 20 inches. 2 spans. Thickness of cement above Ferroinclave (2 sand to 1 Vulcanite cement). $\frac{1}{2}$-inch wall plaster (gypsum) below Ferroinclave

13 On account of the uniform strength of even the thin slabs of Ferroinclave, when cemented, it is possible to construct steel buildings with purlins spaced the most economical distances apart, and its low weight per square foot of roof keeps the material required in the structure of the buildings itself and the purlins down to the lowest limit of any possible form of fire-proof construction. No wooden forms, or moulds, are required for the application of the Ferroinclave or the cement to the same, and in that way a large saving, both in time and money, is effected in applying it to the roof.

14 The sheets ordinarily do not rest directly uponthe purlins, but instead rest on a $\frac{3}{8}$" square strip of iron, or hardwood, in the middle of the purlin. This space between the purlin and the lower edge

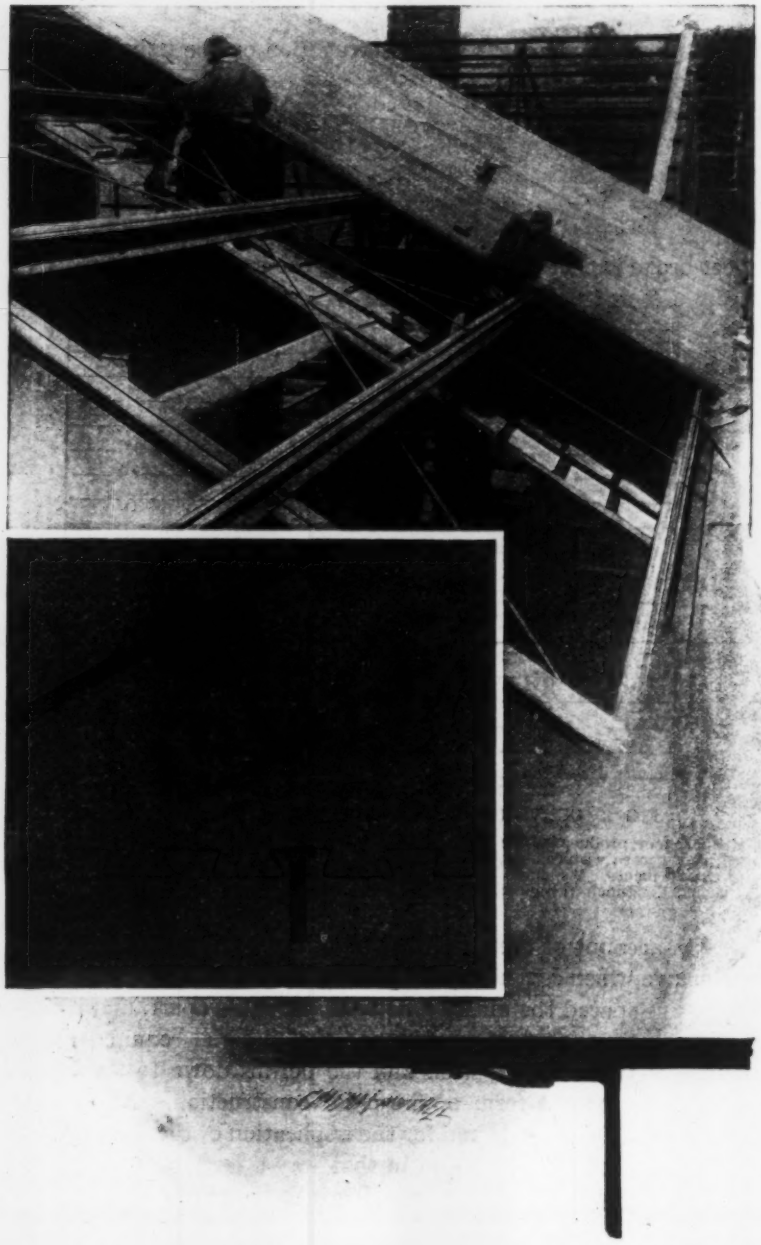


FIG. 4 FERROINCLAVE ROOFING AND SIDING

of the Ferroinclave is filled up with cement when the under side is cemented, thus keeping the steel clear of the purlin itself, or entirely air-tight and weather-tight in the cement itself, preventing any deterioration from exposure. From tests made, these sheets after being covered and in use for a term of years show no deterioration where they are covered only $\frac{3}{8}''$ above and below the corrugations with a mixture of one part of cement to two of sand.

15 In many cases, on account of imperfect roof structural work, both as to alignment and as to solidity against initial springing and movement of its parts when the building is in use, the cement after

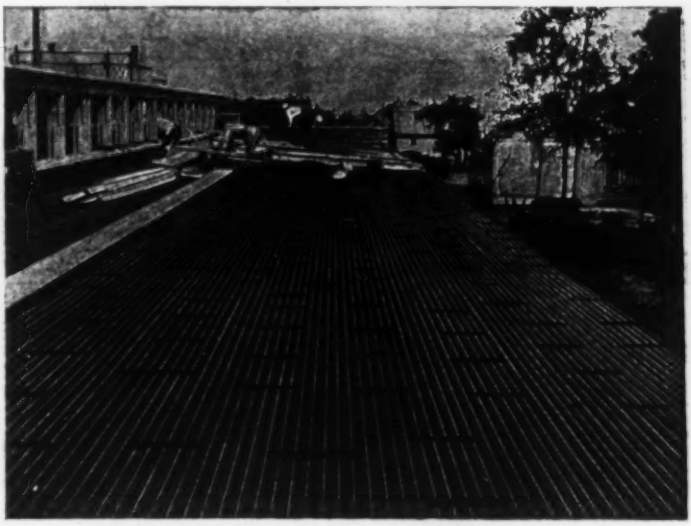


FIG. 5 ROOFS WITH FERROINCLAVE IN PLACE READY FOR CEMENTING

being placed on the Ferroinclave on the roof will sometimes develop cracks, due to separating it before it has become perfectly set. These cracks show up only after the cement has hardened. In such cases it has been found best to guard against any deterioration of the roof that may be due to leakage through these cracks to the sheet metal after the roof is finished and thoroughly dried and hardened, by covering the same with a thin covering of asbestos covering, or other similar good roofing material, stuck on with the proper consistency of asphalt.

16 The Ferroinclave sheet, owing to the form of its corrugations, lends itself admirably to forming into almost any shapes desired,

without distortion of the straightness of the corrugations or the width of the plate itself. It may be bent squarely across the corrugations without widening the sheet, as well as bent diagonally. The sheets may be rolled into any curve after they are in the form of the Ferroinclave as readily as any solid plate, by simply passing them through the bending rolls. This makes it possible to use the sheets for the forming of cornices, arches, and any ornamental work that may be desired to be used in conjunction with the regular construction and where the whole is to be covered with cement. It is particularly adapted to the construction of the risers and treads of stairways and

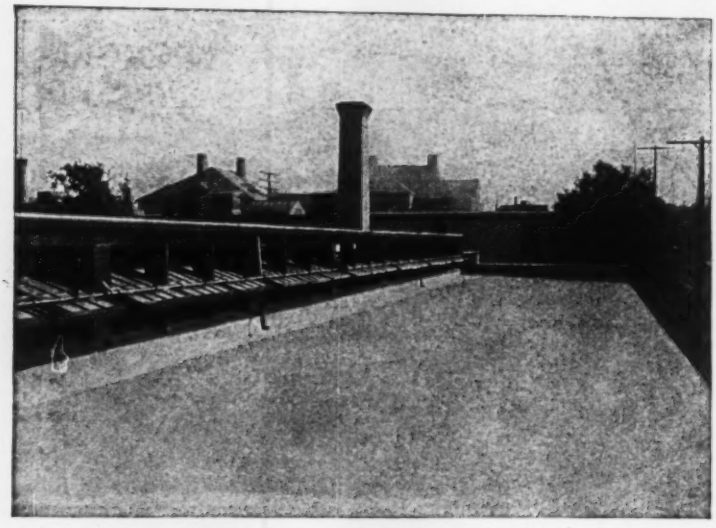


FIG. 6 ROOF CEMENTED FOR WATERPROOF COVERING

steps. Excellent fire-proof bins have been constructed with it, both in the ordinary flat structural form as well as the suspended type, the Ferroinclave sheets spanning from suspension strap to suspension strap to which they are riveted, and afterwards covered with the proper thickness of cement on top and the covering below to give the necessary strength. Floors for gas houses, as well as the coal bins for the same, have been very successfully constructed in this way of the Ferroinclave, and the fire resisting qualities, of course, are such as to be able to quench the coke directly on the floor.

17 Generally the cost per square foot of the Ferroinclave roof completed varies from twenty to twenty-four cents, according to the

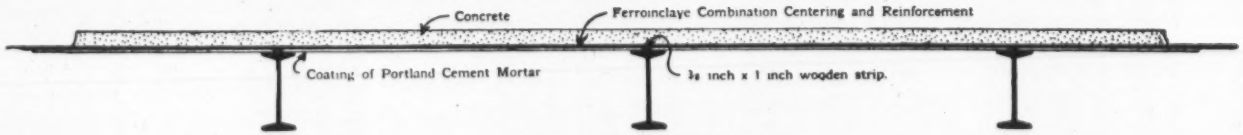

Concrete
Ferroinclave Combination Centering and Reinforcement
Coating of Portland Cement Mortar
3/8 inch x 1 inch wooden strip.

FIG. 7 FLAT FLOOR

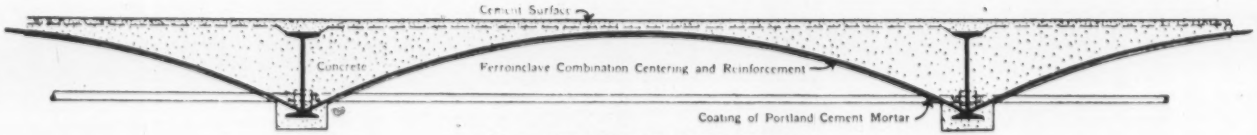


FIG. 8 SEGMENTAL ARCH FLOOR

location and the cost of suitable Portland cement that is used in it. The saving of the additional structural material in the building itself that would be required for the heavier forms of fire-proof roofs, more than makes up for any reduced cost of such roof covering itself.

18 The Ferroinclave is equally applicable to the siding of the buildings and has been very successfully used for the purpose, particularly in large shop and warehouse constructions.

19 A good Portland cement, with a mixture of two parts of sand, after thoroughly setting, has about the same co-efficient of expansion as steel, and in consequence, when applied to the continuous sheet of Ferroinclave, the difference in temperature has little or no detrimental effect.

SAW-TOOTH SKYLIGHT IN FACTORY ROOF CONSTRUCTION[1]

By FRED S. HINDS, BOSTON, MASS.
Non-Member

1 Before Dr. Cartwright invented the power loom in 1785, the cotton spinning factories had attained quite a considerable growth in the Lancashire District of England.

2 When the cotton loom came into practical use, weaving was carried on in the homes of operatives, up to the time when, with the increase in cotton weaving and the advent of the power loom, it devolved upon the progressive operator to branch out into a new plant and set up a few power looms, as a weaving establishment. This naturally was a one-story building and in time was designated as a "weave shed." Thus was commenced a system in textile manufacture which became popular, and is today in England and on the Continent. The spinning factory produces the yarn and the weave shed the cloth.

3 As these weaving companies changed from plain to fancy and colored weaving, and increased the width of the weave sheds to gain greater area, some method of roof lighting became necessary. Thus necessity, the mother of invention, produced the saw-tooth form of roof skylights for lighting the center of the wide one-story buildings.

4 The English and Continental manufacturers were not long in appreciating the value of this method of lighting. The first use was on machine shops making cotton machinery. Today they are found on all kinds of manufacturing plants.

5 The principle in this so-called "saw-tooth" form of skylight is the focusing of a strong north light upon the work in process. This is secured by the green-house type of sash, applied to one side of the saw-tooth and exposed to the north light, the glass being set at such an angle as not to admit the direct rays of the sun. This type of sash

[1]To be presented at the New York meeting (December, 1906) of the American Society of Mechanical Engineers, and to form part of Vol. 28 of the Transactions.

reduces to a minimum the wood work, and thus minimizes the obstruction of light and the casting of shadows.

6 The result is a practically continuous window of glass, which gives a far greater lighting area than wall and windows, or than skylights placed in the usual manner at intervals.

The skylights may run across the building, or lengthwise of the building, so that the glass may face to the north. Placed across the building, they are somewhat simpler in construction and thus less expensive.

METHOD OF CONSTRUCTION

Today there are two constructive designs in applying these skylights; one English and the other American.

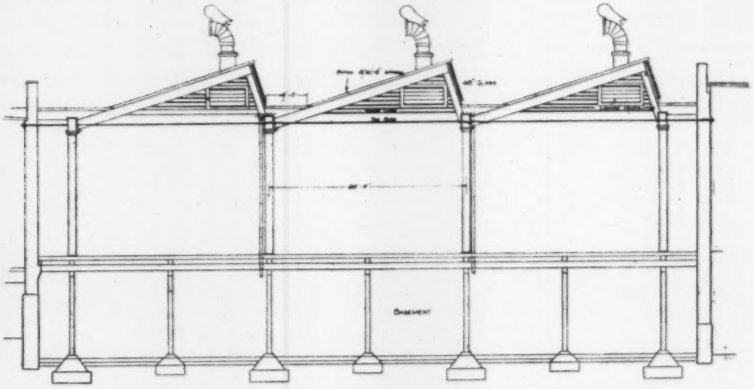


FIG. 1 STANDARD SAW-TOOTH SKYLIGHT IN MILL CONSTRUCTION
OVER A DEPARTMENT OF THE FIBERLOID COMPANY'S PLANT, INDIAN ORCHARD, MASS.
NOTE THE FLAT ROOF BETWEEN SKYLIGHT AND THE VENTILATORS

7 The English design is in the true form of saw-tooth; the American, in the modified form, or semi-saw-tooth flat roof design.

8 The English design was Americanized by the writer, as shown by the accompanying illustrations and photographs, to meet the conditions of our rigorous and changing climate.

9 In 1885, when associated with a mill architect and engineer, the writer was called upon to design some method of roof lighting on a one-story addition to be built in a mill yard area, formed by three buildings in the shape of the letter "U." The problem was to light this area and project light into the first story of the then existing buildings so as to make up for the loss of light due to roofing over the yard area.

10 This same year the writer happened upon an English type of saw-tooth lighted weave shed in connection with a mill plant in the same neighborhood.

11 Upon examination it was found to be giving trouble from leaks. In this type of roof the acute angle formed by the two sides of the skylight was finished in the form of a gutter, made up of sheet metal. These gutters fill up with snow and water which, melting and freezing, cause excessive expansion and contraction, and the result is cracks and broken joints.

12 The writer, profiting from this experience, designed a semi-saw-tooth flat roof. In this type the space between the skylight was

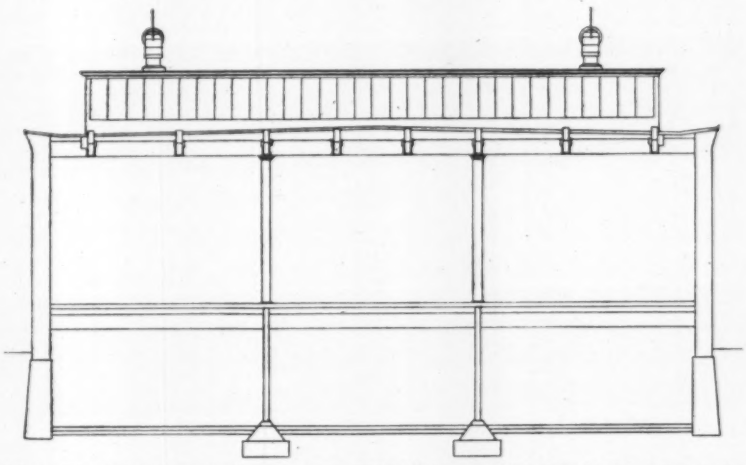


FIG. 2 FRONT VIEW OF SAW-TOOTH SKYLIGHT, FIBERLOID COMPANY'S PLANT

finished in the usual gravel roofing, the slant of the roof conveying the roof-water to the end of the skylight, where it enters the gutter.

14 The angle of the glass is designed by some at 60°, but when the sun is in the zenith it will shine through these skylights. This matter has been lost sight of, as one of the leading features in the principle of saw-tooth skylights is the elimination of the direct rays.

For the South the writer has used 77° and for the North, 71°.

15 In my later designs I have reduced the wide flat roof space between the skylights, and somewhat reversed the modification, returning more closely to the English system, but at the same time preserving a narrow flat roof between each skylight. Varying in width from 24″ to 48″, according to circumstances. (See Figs. 1, 2 and 3.)

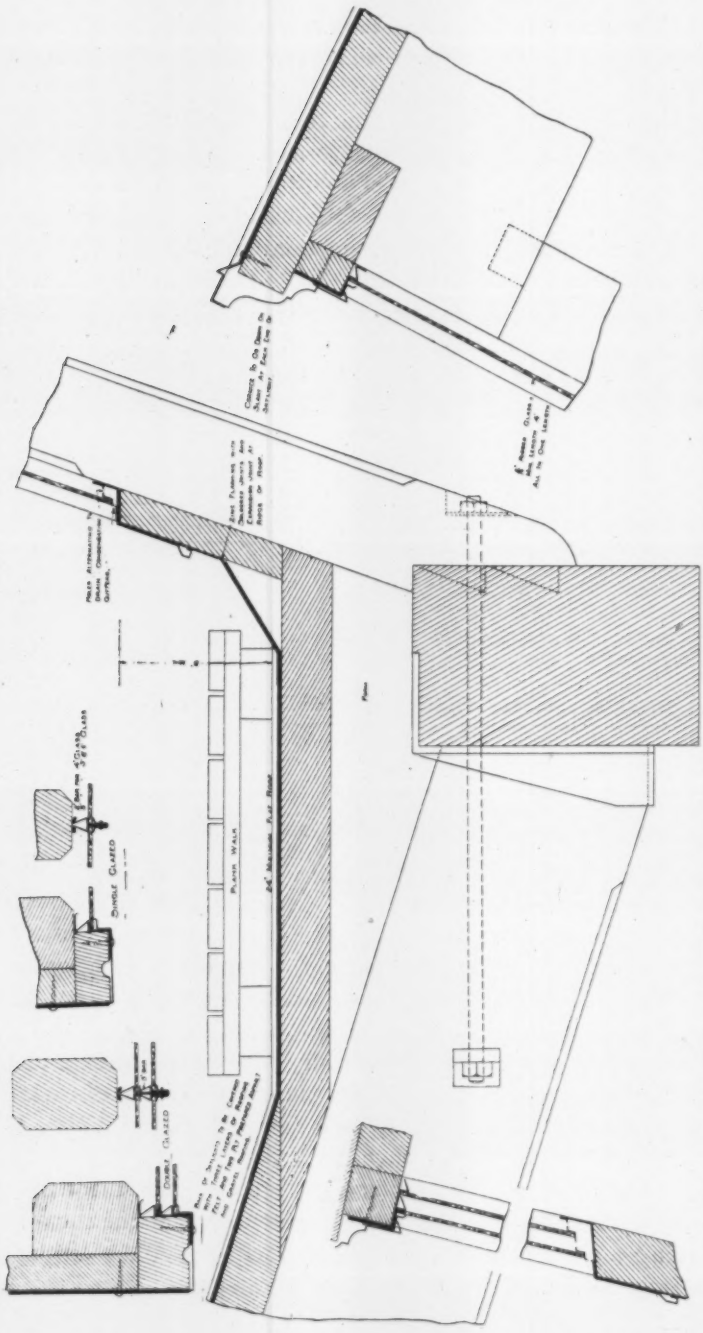


FIG. 3 DETAIL OF AMERICANIZED SAW-TOOTH SKYLIGHT FOR FACTORY ROOFS

16 The flat gravel roof was then reduced from ½″ to ¼″ pitch to the foot, in order to convey the water away in the usual manner and avoid the building up of such high forms as would be necessary with ½″ pitch.

18 The height of the glass is based entirely on the class of manufacture and amount of light required. Four, five and six feet have been my usual basis to work from in determining the size to use. Four feet high, every 20′, is good for general use. Five feet is used for special cases, such as high erecting shops, and the six feet for cases where extra strong light is required.

19 In the year 1900 the writer was called upon to design, in connection with the planning of a southern cotton factory, the weave shed for weaving pattern fabrics. In adopting the saw-tooth skylight, all cross timbers had to be eliminated to avoid the casting of shadows.

20 Appreciating the value of north light and to avoid any direct sun rays, the sash was set at an angle of 77°. This angle, which brings the sash only 13° from the vertical, and therefore not at a great inclination, led to the belief that the elaborate trussed form in framing these skylights was entirely unnecessary to resist this small amount of thrust. I therefore, adopted the tie-rod as the lower chord spanning from column to column, anchoring at each end wall.

22 Fig. 3 illustrates the various details of my latest skylight design and it will be noted that both the double glazing and single glazing are represented. I would draw particular attention to the details of the metal bars. The bars and the bottom of the glass are provided with small gutters for collecting any condensation, and openings are provided in the horizontal metal work for letting out the water as it collects.

23 The double glazing is necessary for some manufacturing plants in the North, but only single glazing is used in the South.

24 The flat gravel space between each skylight and the method of flashing are also detailed.

25 One element of weakness in the construction of some roofs of this type is that the galvanized iron is continued down onto the roof and becomes a part of the flashing. True flashing, and the best, should be in about 10 oz. zinc, running up behind the counter-flashing, or outer flashing, of the skylight.

26 Fig. 3 also shows the slat walk which it is wise to provide in northern skylights, intended not only to walk upon but to facilitate the shoveling off of snow without destroying the gravel roofing.

27 This leads to the subject of snow and whether it is detrimental to the use of skylights.

28 As the prevailing winds in snow-storms are either from the north-east or north-west, it is found to be true (according to observations in a locality in Massachusetts where this style of skylight is very popular) that the wind in a high storm will blow the snow out, because of the somewhat funnel or grooved shape of the skylights. However, suppose they do fill up somewhat with snow, it is not a great expense to hire cheap labor to shovel out this snow, as through our whole winter period heavy storms are only occasional. The cost of shoveling out the snow is a very small expense, as compared to the enhanced value that fine lighting gives to the production of the plant.

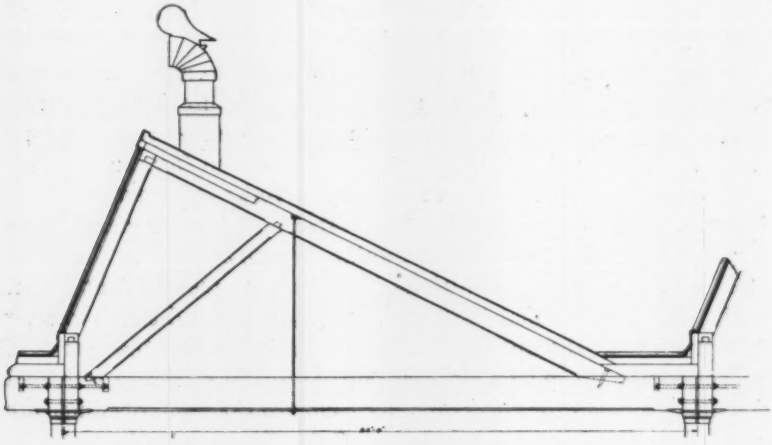


FIG. 4 ELABORATE TRUSSED FORM OF SAW-TOOTH SKYLIGHT

29 It must be conceded that, with a monitor skylight, in a drifting storm, the vertical side would resist the snow and pile it up, and naturally get the same result as with the saw-tooth. Right here the English system would show its serious defect. The advantage of the flat roof is that it spreads out the saw-tooth into a wider area and the snow cannot pile so deep as in the "V" form.

30 Fig. 4 illustrates the elaborate trussed form of framing. Fig. 5 a similar form in reinforced concrete. I believe it is entirely unwarranted as it increases expense in construction and becomes an obstruction to its own light.

31 Fig. 5 shows two very weak points.

32 First, you will note at "A" that the tin roofing forming the gutter, or flat valley, runs up under the slag or gravel roofing, as you would flash under a slate roof. This is at a vertical wall. The same criticism applies at the gutter formed by the skylight itself, or at "B."

33 It is well known in building construction that the worst form of gutter is to have the slant of a roof strike up against a vertical wall where a gutter, or flat valley, must be constructed to carry away the roof water. It makes a very acute angle in which snow and water can collect. The water is taken up by capillary attraction and percolates through some crack in the roofing higher up than the highest point of the tin-work which runs up under the gravel roofing.

34 Some designs have the sash set vertically. This is uncalled-for as, with the same height of glass, if sash is set at an angle, the

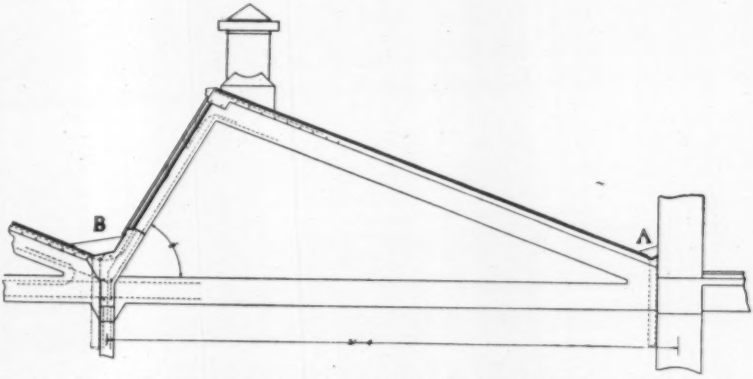


FIG. 5 SAW-TOOTH SKYLIGHT IN REINFORCED CONCRETE, WITH HEAVY CONCRETE BEAM AS BOTTOM CHORD OF TRUSS

area of direct rays of light is increased. There is also less length of slant for the back of the skylight and thus less roof area to cover.

35 This vertical design was used for the purpose of hanging the sash with weights or on a pivot.

The slant from the vertical is so small there is no trouble from the weather beating in.

SASH CONSTRUCTION

37 The sashes are constructed either of wood or sheet metal. If of wood, the glazing is with putty; if of metal, the glazing is done without putty and bars are formed to take care of condensation.

38 With reference to "wood versus metal skylights," and what metal workers are doing under contract at the present time. The

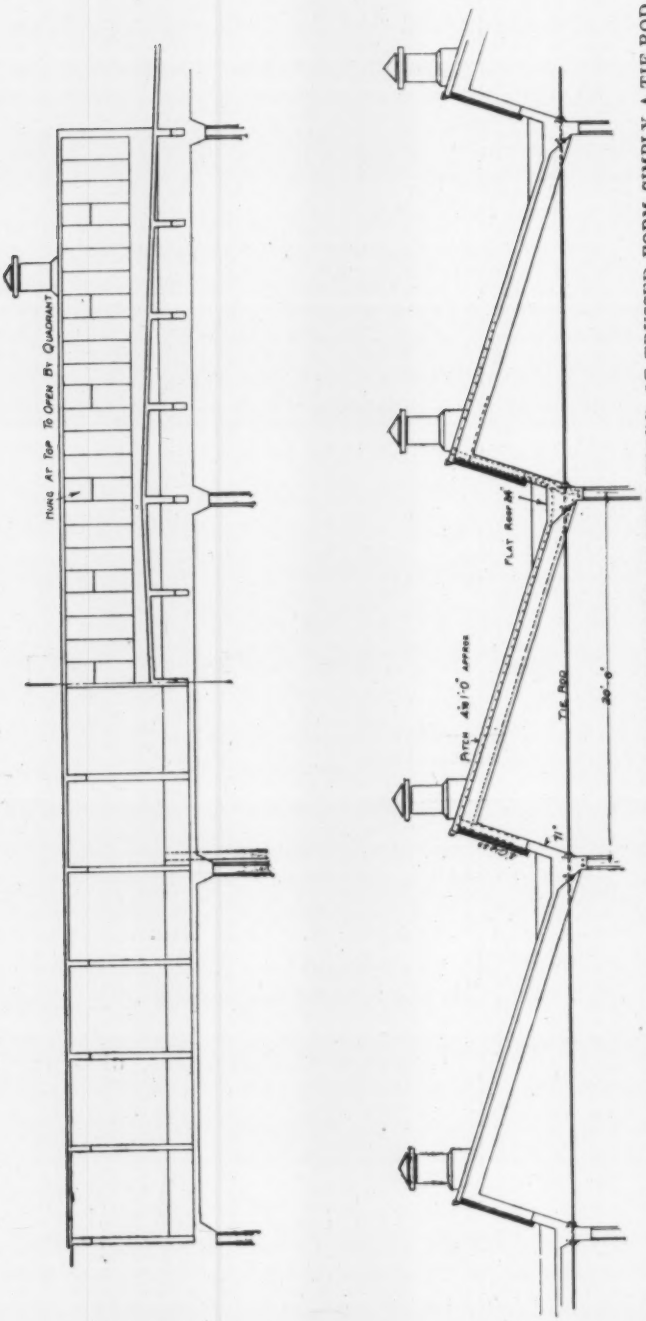


FIG. 6 SAW-TOOTH SKYLIGHT IN REINFORCED CONCRETE WITH THE BOTTOM CHORD OF TRUSSED FORM SIMPLY A TIE ROD AT THE COLUMN LINE

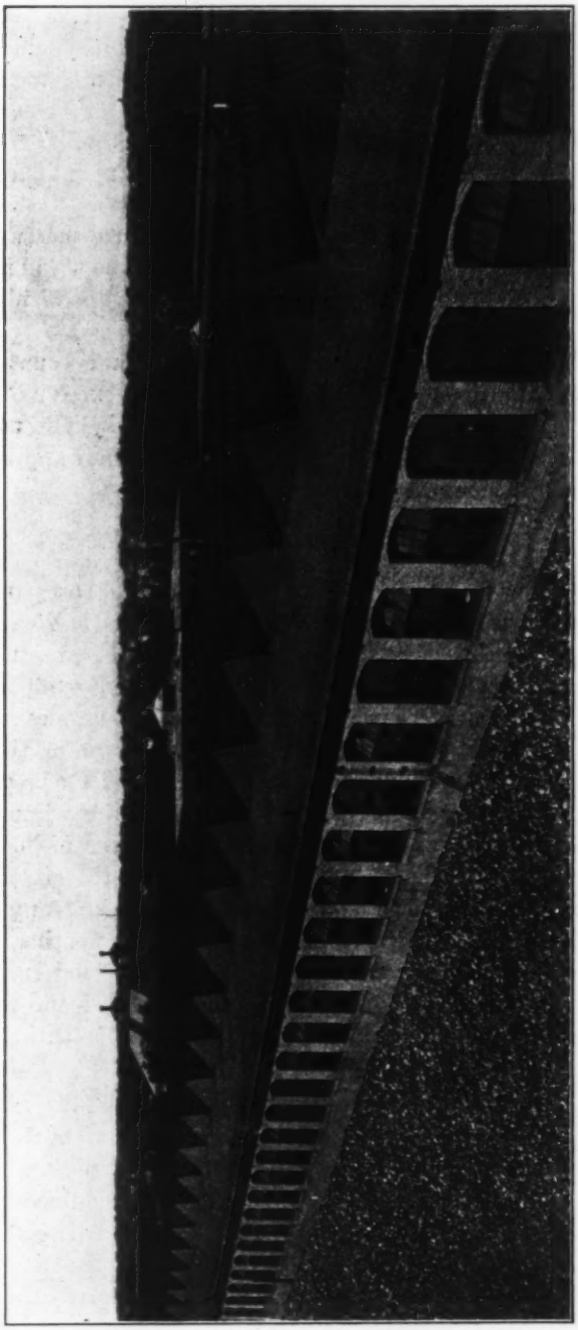


FIG 7 SAW-TOOTH SKYLIGHT OVER ERECTING SHOPS OF B. F. STURTEVANT COMPANY'S PLANT
THEY HAVE THE NARROW FLAT ROOF BETWEEN BUT DO NOT SHOW ANY INDICATION OF VENTILATION

following is a quotation from a letter on the subject. "We have a contract at present for changing over four saw-tooth skylights about 200′ long x 15′ glass opening, from wood construction to metal construction. Also two saw-tooth skylights that we are erecting in metal. These are about 90′ long x 10′ 6″ glass measure. Heretofore the saw-tooth skylights for this company have been built in wood and a departure was made in favor of metal."

39 The one which is referred to as 10′ 6″ glass measure and 90′ long is illustrated by Fig. 9 and Fig. 10, which you will note is not a continuous skylight but a number of skylights with spaces between.

40 These were designed, no doubt, in this way on account of the saw-teeth running lengthwise of the building. This excessive height could have been overcome by forming a continuous skylight, utilizing the spaces between, thus reducing the height of the glass and making up for it by this increase in length.

VENTILATION

41 The subject of ventilation, in connection with this particular class of skylight, has gone through changes along with the vicissitudes of the skylight itself. When these skylights were first introduced on weave sheds of cotton factories, no ventilation was provided.

42 Later, as the skylight manufacturers developed new inventions, the Louvre ventilator was adopted and used in the end of the saw-teeth, as a substitute for round windows, which may have been hung on swivels. Next followed the usual style of galvanized iron ventilator, common in metal skylights used on other classes of buildings. The latest method is to hang one-half the length of the glass at the top and control by the usual quadrant for opening at any angle. (See Fig. 7-A.) These are good in periods of clear weather and in connection with the roof ventilators, give a very good current of air. In stormy weather these side lights must be closed, and the ventilation is taken care of by the Louvre and the roof ventilators.

ROOFING

43 The most approved practice for covering the back of these skylights is some form of asphalt roofing, the method of applying depending upon the angle, or slant, of the roof. Those which have a slant of 4″ to 1′ 0″ can be covered with the usual asphalt felt roofing and covered with gravel, the same as a flat roof. If the slant is greater, then the two upper layers of felt should be applied in what is called

FIG. 8 INTERIOR VIEW—B F. STURTEVANT COMPANY'S ERECTING SHOP, ILLUSTRATING TRUSSED TYPE OF CONSTRUCTION

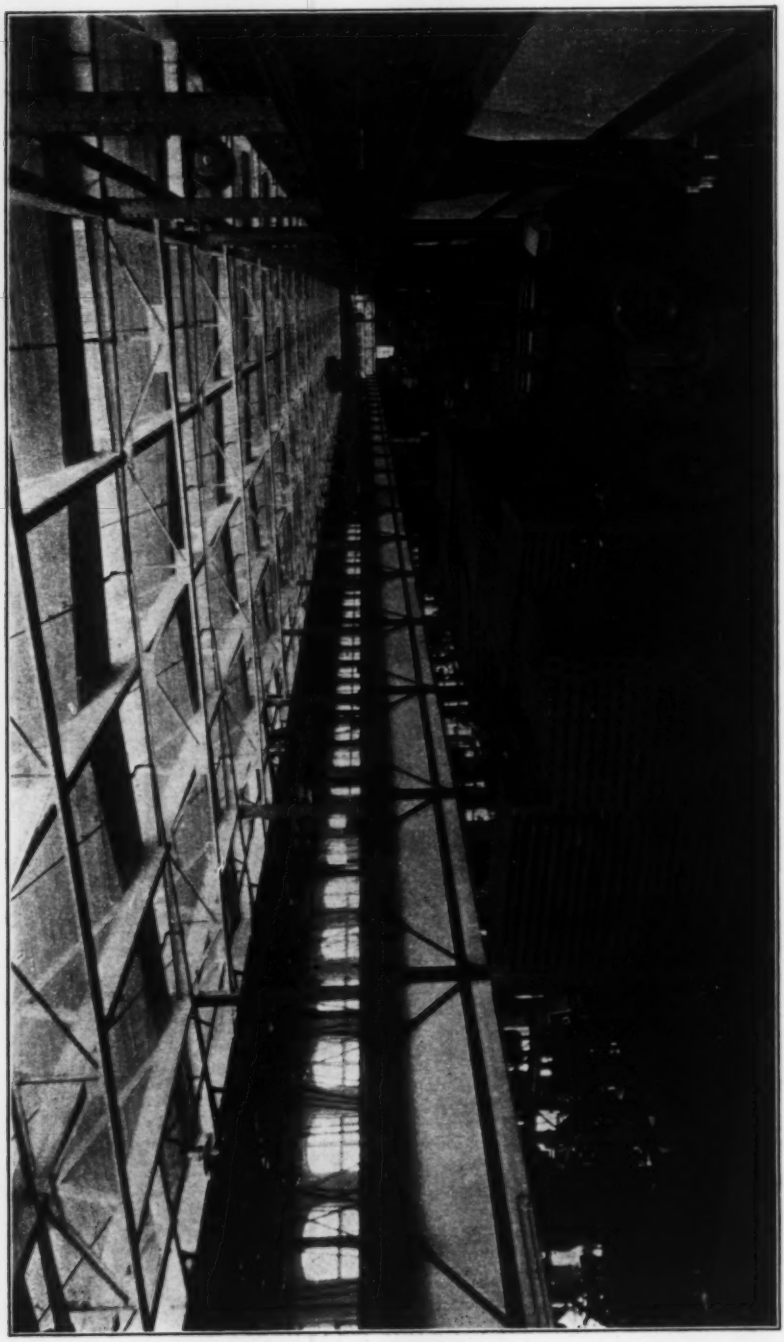


FIG. 9 ERECTING ROOM OF B. F. STURTEVANT COMPANY'S SHOP, ILLUSTRATING THE FINE LIGHTING OF CENTRAL DIVISION

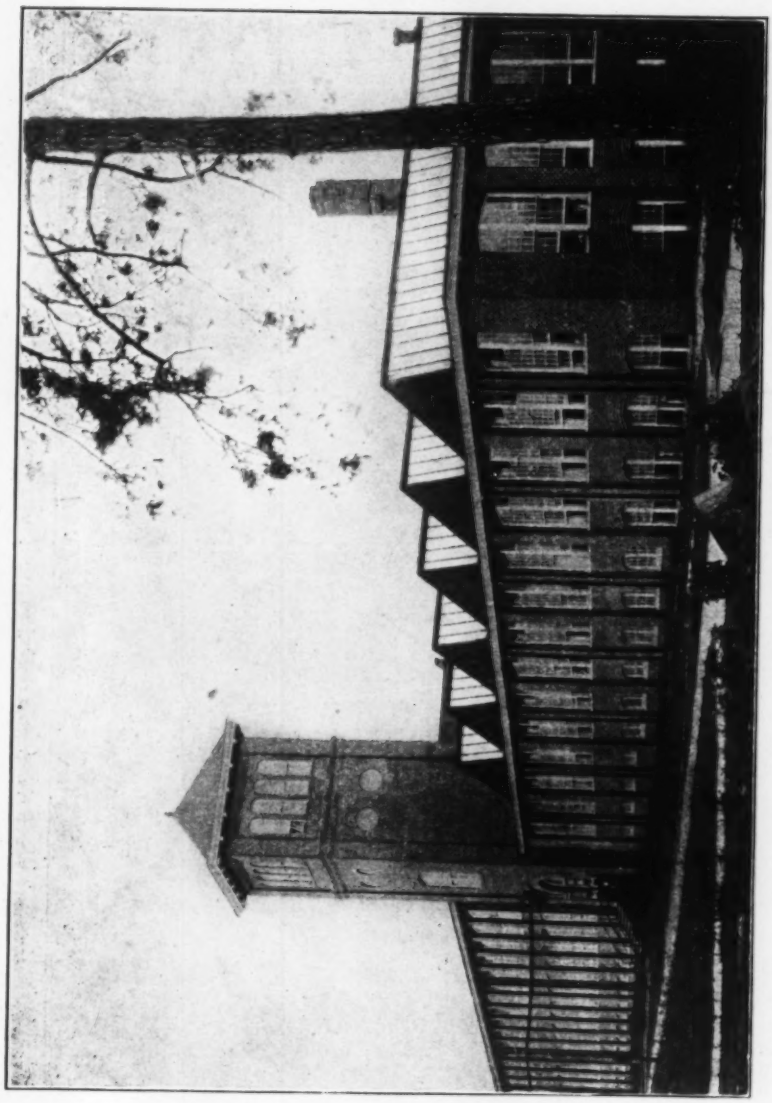


FIG. 10 ROSEMARY MANUFACTURING COMPANY'S COTTON FACTORY, ROANOKE RAPIDS, NORTH CAROLINA

FIG. 11 ROOF OF GENERAL ELECTRIC COMPANY'S SHOP AT LYNN, MASS.
NOTE THESE ARE NOT CONTINUOUS SKYLIGHTS AND IN WOOD CONSTRUCTION WITH SLATE ON LONG SLANT

"prepared gravel asphalt roofing." The flat spaces between the skylights can be of the usual coal tar, felt roofing, and gravel, unless one prefers to have it all asphalt at a slightly increased cost.

44 Saw-tooth skylights do not add to the architectural beauty of a factory building and, therefore, I have studied to keep them down to a reasonable height, and at the same time make them high enough to give the amount of light required.

REINFORCED CONCRETE

The use of reinforced concrete in factory buildings suggests its adaptability to saw-tooth skylight construction.

46 Fig. 6 illustrates how this "Americanized" saw-tooth form can be very simply constructed in reinforced concrete and embody in it all the features necessary.

APPLICATION

49 Saw-tooth skylight construction is not only adapted to cotton factories but to factory buildings, machine shops and for all kinds of manufacturing plants, where better lighting is required than can be obtained from side windows. It is superseding the common monitor roof and is especially adapted for use over erecting rooms and crane rooms of machine shops. It solves the problem of the one-story flat roof machine shop and factories, where this style of construction is desirable and wide buildings are required. In shop economics, and with the extensive area of modern plants, the monitor skylight compels an excessive length in buildings, while the saw-tooth skylight admits of a proportionally greater width and less length, hence giving a more compact arrangement of the shop departments and a thus greater available area of floor space.

50 Where land is valuable, it is applicable to the two-story shop or factory, if special provision is made for lighting the first story. My latest application to a machine shop was a design for the John Thomson Press Company, of an 80′ shop erected at Long Island City in 1905, while acting as consulting architect. This width of 80′ had two rows of columns, thus practically three 25′ divisions.

51 The manufacturer's general plan was to use the two outer divisions of first story for heavy tools and the center division for tool room, storage, etc., and the second story for light machine tools. Over this second story, the introduction of the saw-tooth skylight is applicable and very practical. Its practical value is in the improved arrangement of tools and benches. Instead of running the benches

around the room against the walls, they can be run across the room; first benches, then tools alternating down the length of the shop, depending on the nature of the product. With this system a greater production is sure to follow and with the strong roof light, a higher degree of workmanship.

52 Figs. 7, 8, 9, 10 and 11 still further illustrate the various applications of this form of skylight.

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NOVEMBER, 1906

CONTENTS

SOCIETY AFFAIRS - - - - - - - - - - - - - 95
Convention Notes
Miscellaneous News
PROPOSED AMENDMENTS TO THE CONSTITUTION - - - - - - 101
PROGRAM OF THE ANNUAL MEETING - - - - - - - - 103
RAILWAY TRANSPORTATION NOTICE - - - - - - - - 106
OBITUARY - - - - - - - - - - - - - - 110
PRESIDENT'S LETTER - - - - - - - - - - - - 111
EMPLOYMENT BULLETIN - - - - - - - - - - - 113
PROFESSIONAL RECORDS - - - - - - - - - - - 116
OFFICERS AND COUNCIL - - - - - - - - - - - 161
COMMITTEES - - - - - - - - - - - - - 162
PAPERS:
The Evolution of Gas Power. Mr. F. E. Junge - - - - - 163
Producer Gas Power Plant. Mr. J. R. Bibbins - - - - - 197
A High Duty Air Compressor. Prof. O. P. Hood - - - - 221
Boiler and Setting. Mr. A. Bement - - - - - - - 245
Steam Plant of the White Motor Car. Prof. R. C. Carpenter - 255
Saw-Tooth Roofs for Factories. Mr. K. C. Richmond - - 287
Weights and Measures. Mr. H. R. Towne - - - - - 301
A Mechanical Engineering Index. Prof. W. W. Bird and Prof. A. L. Smith - - - - - - - - - - - - - 335
The Flow of Fluids in a Venturi Tube Mr. E. P. Coleman - 391
Tests of a Plunger Elevator Plant. Mr. A. J. Herschmann - - 407
Improved Transmission Dynamometer. Prof. W. F. Durand - 425
Steam Turbine Characteristics. Mr. Hans Holzwarth - - 433
CONTRIBUTED DISCUSSION:
Mr. C. H. Churchill. Ventilation of Boston Subway - - 459
Mr. E. N. Hunting. Ferroinclave Roof Construction - - 462
Prof. J. E. Sweet. Saw-Tooth Skylight in Factory Roof Construction 465
The Secretary. Machine Screw Report - - - - - - 466